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IDENTIFIERS *Computer Assisted Manufacturing; Computer Technicians

ABSTRACT

Seven student learning guides are provided for an industrial electrical maintenance program at the secondary, postsecondary, or adult level. Each learning guide is composed of these component parts: a title page that states the task, purpose, program and task numbers, estimated time, and prerequisites; an optional learning contract that includes terminal performance and intermediate objectives; materials for each intermediate objective; and a criterion exam. For each objective some or all of the following may be included: learning steps/activities and related resources, information sheets, procedure sheets, activity sheets, and a self-help evaluation instrument. The learning guides cover the following seven tasks: identifying fluid system schematic symbols, describing unified technology concepts, identifying fluid system components, connecting fluid system valves, connecting fluid system actuators, connecting venturi vacuum generator, and describing pressure and force in a fluid system. An appendix contains a competency-based task listing by job titles for the industrial electrical maintenance program. (YLB)

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Industrial Electrical Maintenance Learning Guides

and

Task Listing by Occupational Titles

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Product Abstract

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3. Please check one: New material X Revised material ____ Field-tested material ____
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____ 10 Industrial Arts Education
____ 16 Technical Education
X 17 Trade and Industrial Education
____ 22 Cooperative Education
____ Career Education
____ Other (Specify) ____

8. Education Level:

____ Pre-K Thru 6
____ 7-8
____ 9-10
X 11-12
X Post-Secondary
X Adult
____ Teacher (Pre-service)
____ Administrator (Pre-Service)
____ Other (Specify) ____

9. Intended for Use By:

X Student
X Classroom Teacher
X Local Administrator
____ Teacher Educator
____ Guidance Staff
____ State Personnel
____ Other (Specify) ____

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X Regular
____ Disadvantaged
____ Handicapped
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____ Other (Specify) ____

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16. General Description (State the general objective and suggested method of use. Summarize the content and tell how it is organized. Write the description so that it can be used to promote the material. Continue on back of this sheet or on another sheet, if necessary.)

Competency-based learning guides for learning basic skills/knowledge

17. Person Completing this Abstract. Richard W. Glogovsky

Full Address
Lake County Area Vocational Center
19525 West Washington Street
Grayslake IL 60030

LEARNING GUIDE TITLES:

1. Identify fluid system schematic symbols
2. Describe unified technology concepts
3. Identify fluid system components
4. Connect fluid system valves
5. Connect fluid system actuators
6. Connect venturi vacuum generator
7. Describe pressure and force in a fluid system

LAKE COUNTY AREA VOCATIONAL CENTER

COMPETENCY-BASED INDIVIDUALIZED VOCATIONAL EDUCATION INSTRUCTION

STUDENT LEARNING GUIDE

Produced By M.H. WHITMER Date 1/85

TASK: IDENTIFY FLUID SYSTEM SCHEMATIC SYMBOLS

PURPOSE: You must understand the principles of fluid systems as they apply to robotics and automated manufacturing. The intermediate objectives under this task presents the schematic symbols and interconnections to help you achieve the needed understanding. The modern electrical maintenance person knows how fluid systems work so that troubles can be identified and repairs effected rapidly.

INDUSTRIAL ELECTRICAL MAINTENANCE

Program	Task	Est.Time	Prereq
17.1002	210	2 hrs	NONE

edk

LEARNING CONTRACT (optional)

1. STUDENT DATA

NAME _____ SOCIAL SECURITY NUMBER _____

LENGTH OF CONTRACT (NORMAL TIME IN HOURS) _____

2. TERMINAL PERFORMANCE OBJECTIVE

Given a written evaluation, you will identify fluid system symbols. You must score 100% on the written test for this objective.

2a. INTERMEDIATE OBJECTIVE(s)

1. Identify the physical parts location on the pneumatics trainer.
2. Identify the graphic symbols for the components used fluid systems.

3. AGREEMENT

I, _____ agree to complete the above stated terminal performance requirement within _____ to _____. I further recognize that the conditions of the contract (performance and time agreement) report my ability to perform the requirements of the occupation and record my progress.

_____ Student's Signature

_____ Instructor's Signature (verifies competency)

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INTERMEDIATE OBJECTIVE

Identify the physical parts location on the pneumatics trainer.

LEARNING STEPS (Activities)

1. Read the information sheet cited in resource #1 to learn the function of the trainer.
2. Perform the action called for on the procedure sheet cited in resource #2
3. Complete the self-help performance checklist cited in resource #3 to assure mastery of the objective.
4. Proceed to the next objective

RESOURCES

1. Information sheet #1, page 4, is entitled "Brat 500"
2. Procedure sheet #1, pages 6 and 7 are entitled "Trainer Familarization"
3. Self-help performance checklist #1, page 8 is entitled "Parts Location"
4. The next objective starts on page 10.

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INFORMATION SHEET #1

BRAT 500

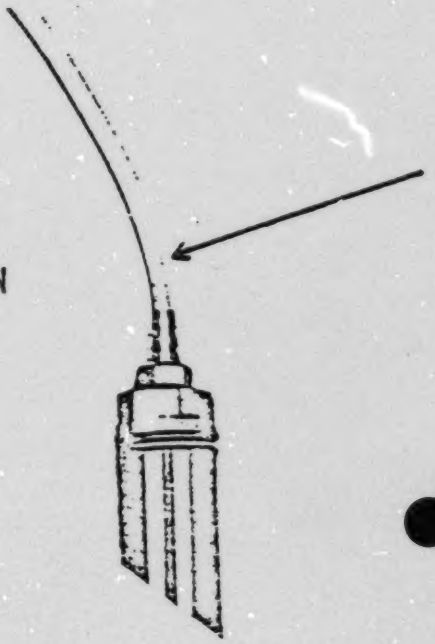
CONNECTING COMPONENTS AND BUILDING CIRCUITS

Pneumatic connections between components are made with 1/16" pneumatic tubing and barb fittings. (See the barb fitting in illustration #1). To make connections, slide the tubing over the barb fittings and apply pressure so that the tubing covers the entire barb. You may choose to keep the tubing connected to the output quick disconnects to save class room time.

To remove tubing from components, grasp tubing just above the barb fitting and pull off fitting.

ILLUSTRATION #1

ILLUSTRATION #2



AIR LEAKS

Many experiments will not reflect true component action if any sizeable leaks take place. After a period of tine and continuous use of component circuit acitivities; you may develop a slight air leak at the barb fitting and tubing connection. (See illustration #2). This may occur if the tubing gets stretched out of shape. If this happens, simply cut off the end of the tubing and reconnect.

SYMBOLS

All symbols used on the activities are considered standard by all industrial requirements and are the U.S.A. STANDARD GRAPHIC SUMBOLS, however, when you enter field work you will see some minor variances from schematic to schematic.

CAUTION: AVOID CLEANING TUBING WITH ANY CHEMICAL CLEANING FLUIDS.

INFORMATION SHEET # 1 (Cont.)

SAFETY

Always use care when releasing compressed air near nose, ears, or throat. Serious injury or death have been caused by thoughtless use of compressed air. Recommended operating air pressure of the BRAT 500 should not exceed 60 psi.

Program	Task	Page
[illegible]	[illegible]	3

PROCEDURE SHEET #1

TRAINER FAMILIARIZATION

OBJECTIVE: To identify each operational portion of the BRAT 500 and how to apply them to the following activities.

MATERIALS NEEDED:
1 - BRAT 500
1 - 60 PSI AIR SUPPLY
1 - 115 VAC GROUNDED POWER SOURCE
1 - STUDENT LEARNING GUIDE 210
1 - PENCIL

PROCEDURE USING THE ILLUSTRATIONS ON THE FOLLOWING PAGES, AND FOLLOWING EACH TESTING PROCEDURE YOU WILL HAVE YOUR FIRST OPPORTUNITY TO DEMONSTRATE EACH PORTION OF THE BRAT 500 TRAINER.

NOTE: CHECK OFF EACH STEP THAT YOU MASTER SO THAT YOU WILL RECORD YOUR PROGRESS.

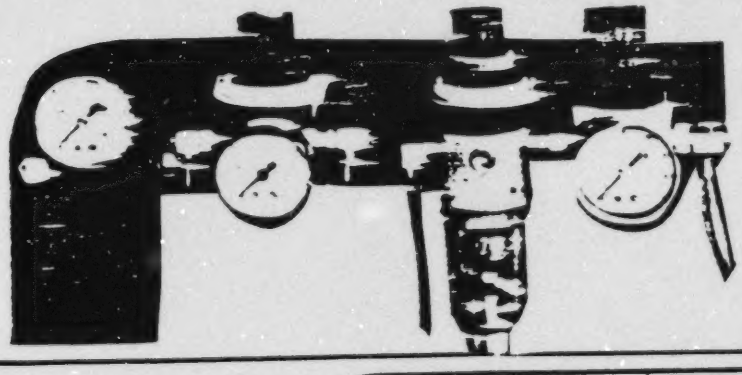
____ STEP #1 - Connect your laboratory air supply to the air inlet connector provided on the BRAT 500 (See Illustration #3).

____ STEP #2 - Connect the three prong grounded line cord on the BRAT 500 to the 115 VAC outlet.

____ STEP #3 - Using the illustration below, locate the instrument and test station panel and observe the following components; TEST GAUGE: used to test and record pressure within a circuit. REGULATED PRESSURE STATIONS: Used to isolate a desired pressure within a circuit. FILTER AND REGULATOR: Used to regulate and filter the incoming air supply to the trainer.

____ STEP #4 - Locate the component storage board, the storage board houses the various components used on the proceeding activities. After each experiment, replace all components to this area to avoid misplacing any components.

____ STEP #5 - Locate the Valve and Manifold Assembly. The valve pack supplied has seven manifolds with two air piloted valves, two electric piloted valves, two manual piloted valves and one blank manifold for expansion or addition of advanced pneumatic kits. All valves are removable and interchangeable with all manifolds.



AIR INLET CONNECTOR

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PROCEDURE SHEET

Step #6

The 12 volt output jacks are located directly below the valve assembly and is used to power the electric piloted single and double solenoid valves. Each output jack is powered by the 12 volt input switches and all operate independent of each other.

Step #7

The Power On/OFF switch supplies the power source for the 12 volt outputs and must be activated to use the electric piloted valves.

Step #8

Locate the Pneumatic Input switches. The input switches activate the corresponding pneumatic output ports when the fast connectors supplied are screwed completely down. The input switches are not used for activating the manual piloted valves, or the electric piloted valves.

Step #9

The work surface is used to assemble circuits using the components supplied.

Step #10

Note that each pneumatic input and output is shown on the illustration with an "a" or "b" assigned. This denotes the A and B ports on the manifolds and will be referred to in various activities. Further explanation of these ports will be discussed in later activities.

Step #11

Adjust the Filter Regulator to read 40 PSI on the gauge.

Step #12

Activate PNEUMATIC INPUT swtich 1A, place a fast cibbect barb on PNEUMATIC OUTPUT PORT 1A and slowly screw it on. What did you observe?

_____

_____

_____

NOTE: ALL FAST CONNECTORS REACT THE SAME.

Step #13

Turn the POWER switch to the ON position. take the leads from the single solenoid electric valve and plug into the 12 volt output jack numbered 1. Place a fast connector on output 3A and activate the 12 volt input switch #1. What did you observe? _____

_____

_____

Step #14

REVIEW EACH OF THE STEPS YOU HAVE JUST COMPLETED AND ASSURE YOURSELF THAT YOU HAVE MASTERED THE CORRECT LOCATION OF EACH PART

PERFORMANCE/PRODUCT CHECKLIST

Program: INDUSTRIAL ELECTRIC MAINTENANCE

Task No:

Identify the physical parts location on the pneumatic trainer.

Student's Name: _____ Date Of Attempt: _____

Evaluator's Name: _____ Evaluation Site: _____

Performance Attempt: 1 2 3 4

Terminal Performance Objective:

Given a written evaluation, you will identify fluid system symbols. You must score 100% on the written test for this objective.

Directions To The Student:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 10 out of 10 points or 100 % for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

Directions To The Evaluator:

The student will contact you when ready for the evaluation. The student must complete the performance within 30 minutes and must score 10 out of 10 points or 100 % and all items marked with an asterisk (*) must be satisfactorily completed.

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CRITICAL ITEMS	ITEMS TO BE OBSERVED OR CHECKED	RATING YES	RATING NO
	Parts location		
	Lever valve		
	Solenoid valve		
	Air piloted valve		
	Test Gauge		
	Output Ports		
	Input indicators		
	Power Indicator		
	Pneumatic inputs		
	Pressure regulator		
	12 volt jacks		

TOTAL POINTS EARNED =

POINTS NEEDED FOR MASTERY = 10
TOTAL POINTS POSSIBLE = 10

INTERMEDIATE OBJECTIVE

Identify the graphic symbols for the components used in fluid systems.

LEARNING STEPS (Activities)	RESOURCES
1. Read the information sheet cited in Resource #1 to learn about the symbols used in fluid systems.	1. Information Sheet #2 page 11-12 entitled "Graphic Symbols".
2. Follow the steps given in Procedure Sheet cited in Resource #2 to relate symbol and physical appearance.	2. Procedure Sheet #2, page 13 to 14 is entitled "Table of Symbols."
3. Complete the self - help evaluation cited in Resource #3 to assure mastery of the objective.	3. Self-help evaluation #2, page 16 entitled "Symbol Identification".
4. Complete the evaluation instrument for this terminal performance objective.	4. See your instructor for the evaluation instrument.
5. Proceed to the student learning guide.	5. See your instructor.

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INFORMATION SHEET #2

GRAPHIC SYMBOLS

Graphic symbols for fluid power diagrams have been developed by the American National Standards Institute (ANSI) to provide a means of communication standards that serve industry and education. The standards serve to simplify design, fabrication, analysis and servicing of fluid power systems; they have no language barriers.

The ANSI Graphic System utilizes elementary geometrical forms to depict components and circuits. These forms include: circles, squares, rectangles, triangles, arcs, arrows, lines, dots and crosses.

The symbols attempt to describe component function rather than construction. In addition, they provide a means of showing how many of the fluid power components operate hydraulically, electrically, manually, etc. The standards include basic symbols which differentiate between hydraulic and pneumatic fluid components and circuits.

In addition to graphic symbols, fluid power systems and components can be illustrated with pictorial and cutaway symbols. Pictorial symbols are useful for showing the interconnections of components, but are difficult to standardize from a functional basis. Cutaway symbols are used to emphasize construction, but are complex to draw and they do not readily indicate functions.

In order to use the system to its maximum potential, the following general rules must be understood and followed:

*Symbols show connection, flow paths and function of components represented. They do not indicate condition occuring during transition form one flow path arrangement to another. Further, they do not indicate construction or values such as pressure flow rate, and other component settings.

*Symbols do not indicate location of ports, direction of shifting of spools or position of control elements on an actual component.

* The position of size of a symbol can be altered, for component emphasis in an circuit, without changing its meaning.

*Each symbol is drawn to show normal or neutral condition of component unless multiple circuit diagrams are furnished showing various phases of circuit operation.

*Arrows used within symbol envelops show direction of fluid flow in a component as used on the application represented, Double-end arrows indicate reverse flow.

INFORMATION SHEET #2

SYMBOLS

All symbols used in the activities are considered standard by all industrial requirements and are the U.S.A. standard graphic symbols. However, when you enter field work you will see some minor variances from schematic to schematic.

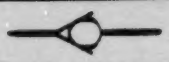
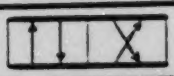
CAUTION

Avoid cleaning tubing with any chemical cleaning fluids.

SAFETY

Always use care when releasing compressed air near eyes, nose, ears, or throat. Serious injury or death have been caused by thoughtless use of compressed air. Recommened operating air pressure of the BRAT 500 should not exceed 60 PSI.

The BRAT 500 requires a 115VAC power source input. The BRAT 500 is grounded and fused and has a 12-16 volt output for safety. If you have any questions about safety procedures, advise your instructor.

PNEUMATIC VALVES	
SYMBOL	DESCRIPTION
	CHECK
	CHECK PILOT OPERATED TO OPEN
	CHECK PILOT OPERATED TO CLOSE
	2 POSITION 2 WAY
	ON - OFF SIMPLIFIED
	2 POSITION 3 WAY
	2 POSITION 4 WAY
	2 POSITION, 4 WAY 5 PORTED
	3 POSITION, 4 WAY PORTS CLOSED, CENTER POSITION
	3 POSITION, 4 WAY, 5 PORTED (Cylinder ports open to pressure in center pos.)
	3 POSITION, 4 WAY, INFINITE POSITIONING (Cylinder ports open to exhaust in center pos.)
	QUICK EXHAUST
	SHUTTLE

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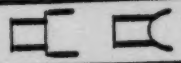
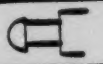
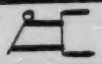
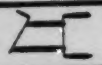
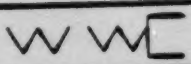
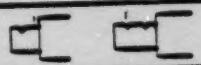
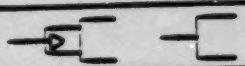
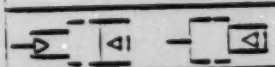
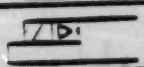
VALVE ACTUATORS

SYMBOL	DESCRIPTION
	MANUAL GENERAL SYMBOL
	PUSH BUTTON
	LEVER
	PEDAL OR TREADLE
	MECHANICAL CAM, TOGGLE ETC.
	SPRING
	DETENT LINE INDICATES WHICH DETENT IS IN USE
	SOLENOID
	INTERNAL PILOT SUPPLY
	REMOTE PILOT SUPPLY COMPLETE SIMPLIFIED
	INTERNAL PILOT EXHAUST
	PILOT EXHAUST TO ATMOSPHERE
	PILOT DIFFERENTIAL COMPLETE SIMPLIFIED
	AND COMPOSITE SOLENOID AND PILOT
	OR COMPOSITE SOLENOID OR MANUAL OVERRIDE
	AND/OR COMPOSITE Solenoid and pilot or manual override
	AND/OR COMPOSITE. Solenoid and pilot or manual override one pilot

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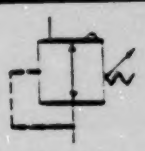
AIR PREPARATION UNITS

SYMBOL	DESCRIPTION
	FILTER SEPARATOR WITH MANUAL DRAIN
	FILTER SEPARATOR WITH AUTOMATIC DRAIN
	AUTOMATIC DRAIN
	LUBRICATOR LESS DRAIN
	LUBRICATOR WITH MANUAL DRAIN
	LUBRICATOR WITH AUTOMATIC FILLING
	AIR-LINE PRESSURE REGULATOR ADJUSTABLE RELIEVING
	AIR-LINE PRESSURE REGULATOR PILOT - CONTROLLED RELIEVING
	AIR-LINE COMBO F R L SIMPLIFIED

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EVALUATION SHEET
SELF-HELP EVALUATION # 3

1. Describe and list four application of pneumatics:

2. Name the three methods of transmitting power:

3. List four advantages and two disadvantages of pneumatic power:

4. What technologies are considered FLUID POWER:

5. What GAS LAWstates, Pressure in liquid or gas in a confined body acts equally in all directions, and always at right angles to the containing surfaces:

6. What is the formula for BOYLE'S LAW:

7. TRUE or FALSE, Pneumatic power is fast to repond to stopping and starting.

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PROGRAM INDUSTRIAL ELECTRICAL MAINTENANCE

CRITERION EXAM

TASK = 210 IDENTIFY FLUID SYMBOLS

DIRECTIONS:

THE PURPOSE OF THIS EXAM IS TO DETERMINE WHETHER OR NOT YOU HAVE UNDERSTOOD THE INFORMATION ON FLUID SYMBOLS AND THEIR RELATED PHYSICAL COMPONENTS.

Each of the questions or incomplete statements below is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A,B,C or D) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer 10 out of 10 items correctly, 100 %.

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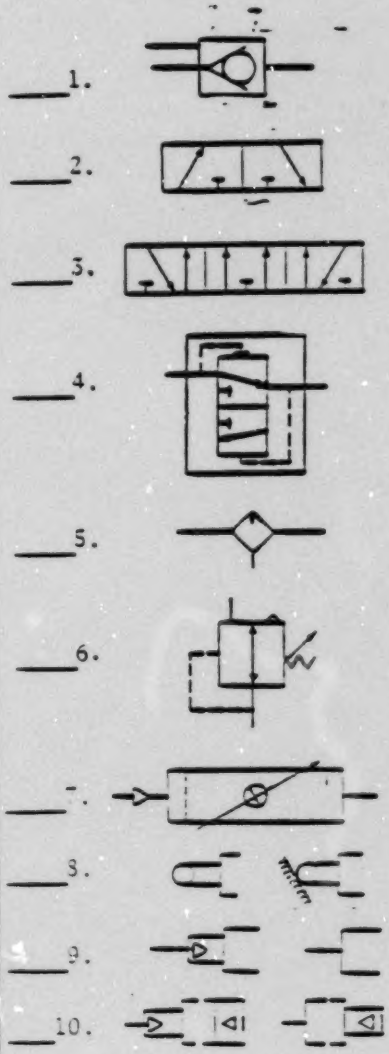
EVALUATION SHEET

CRITERIA EXAM FOR 210

Match symbol with description. Place letter before number.



___1.
___2.
___3.
___4.
___5.
___6.
___7.
___8.
___9.
___10.

A. LUBRICATOR WITH MANUAL DRAIN

B. QUICK EXHAUST

C. MECHANICAL CAM TOGGLE ETC.

D. CHECK PILOT OPERATED TO OPEN

E. PILOT DIFFERENTIAL
COMPLETE SIMPLIFIED

F. 3 POSITION, 4 WAY, 5 PORTED
(CYLINDER PORTS OPEN TO PRESSURE IN CENTER POS.)

G. AIR-LINE PRESSURE REGULATOR
ADJUSTABLE RELIEVING

H. REMOTE PILOT SUPPLY
COMPLETE SIMPLIFIED

I. 2 POSITION
3 WAY

J. AIR-LINE COMBO F R L
SIMPLIFIED

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LAKE COUNTY AREA VOCATIONAL CENTER

COMPETENCY-BASED INDIVIDUALIZED VOCATIONAL EDUCATION INSTRUCTION

STUDENT LEARNING GUIDE

Produced By M.H. WHITMER Date 1/85

TASK: DESCRIBE UNIFIED TECHNOLOGY CONCEPTS

PURPOSE: You must understand the principles of unified technology concepts as they apply to robotics and automated manufacturing. The intermediate objectives under this task present the unified concepts to help you achieve the needed understanding. The modern electrical miantenance person knows the unified technology concepts so that troubles can be identified in the correct system and repairs effected rapidly.

INDUSTRIAL ELECTRICAL MAINTENANCE

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edk

1. STUDENT DATA

NAME _____ SOCIAL SECURITY NUMBER _____

LENGTH OF CONTRACT (NORMAL TIME IN HOURS) _____

2. TERMINAL PERFORMANCE OBJECTIVE

Given a written evaluation, you will describe the unified technology concepts as they apply to fluid systems. You must score 100% on the written test for this objective.

2a. INTERMEDIATE OBJECTIVE(s)

1. Identify the fundamental principles of fluid systems.
2. Describe the methods of doing work in the fluid system.
3. Describe the rate of fluid flow in the fluid system.
4. Describe the similarities of related technology circuits and components.

3. AGREEMENT

I, _____ agree to complete the above stated terminal performance requirement within _____ to _____. I further recognize that the conditions of the contract (performance and time agreement) report my ability to perform the requirements of the occupation and record my progress.

_____ Student's Signature

_____ Instructor's Signature (verifies competency)

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INTERMEDIATE OBJECTIVE #1

IDENTIFY THE FUNDAMENTAL PRINCIPLES OF FLUID SYSTEMS.

LEARNING STEPS (Activities)	RESOURCES
1. Read the information sheet cited in Resource #1 to learn about fluids.	1. Information Sheet #1, pages 4 and 5 are entitled "Fundamentals of Pneumatics."
2. Identify the fluid laws cited in Resource #2 to learn about the gas laws.	2. Information Sheet #2 pages 6 and 7 are entitled "Basic Gas Laws."
3. Complete the self-help evaluation cited in Resource #3 to determine your level of understanding.	3. Self-help evaluation #1 page 8 is entitled "Principles of Fluid Systems."
4. Proceed to the next Intermediate Objective to continue your progress.	4. Intermediate Objective #2 begins on page 9.

INFORMATION SHEET #1

FUNDAMENTALS OF PNEUMATICS

Man has always searched for new ways to extend his physical capabilities by harnessing and using energy produced by nature. The study of power technology concerns energy sources, the conversion of those sources, and the method of transmitting power for many industrial and technical applications. There are three methods of transmitting power: (1.) electrical, (2.) mechanical and (3.) fluid power which includes pneumatics and hydraulics. In this student guide, you will study the control and transmission of power through pneumatics.

Over the past two decades fluid power has had a great impact and influence on American industry. Over 85% of all automated systems depend upon pneumatics and hydraulics for muscle power.

Fluid power is the main source for many applications such as robotics, feeding systems, air cooling and heating, parts positioning and lifting heavy payloads. Many industries such as agriculture, chemical process, construction, materials handling, steel production, transportation and robotics depend upon the use of fluid power.

Some of the advantages and disadvantages of fluid systems are:

ADVANTAGES

1. Clean and safe from fire.
2. Easy to store.
3. Speed, fast response to starting and stopping.
4. Quiet operation if properly muffled.
5. No return line needed.
6. Readily available.
7. Efficient method of multiplying force.

DISADVANTAGES

1. Expensive
2. Has pressure limits.
3. Possible leakage.
4. Compressibility is a safety hazzard.

On the following page, you will see several pictures representing the multitude of applications for pneumatic control and actuation.

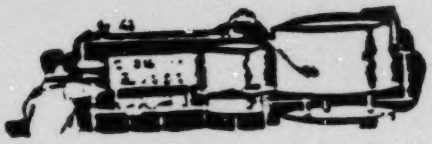
INFORMATION SHEET (Cont.)

FLUID POWER APPLICATIONS WORLDWIDE

aviation

agriculture

chemicals



petroleum

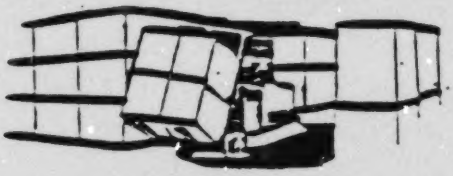
food processing

marine

metalworking and machine tools

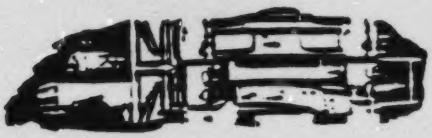
lumber

material handling



construction

mining



steel

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INFORMATION SHEET #2

BASIC GAS LAWS

PASCAL'S LAW:

Pressure in liquid or gas in a confined body acts equally in all directions, and always at right angles to the containing surfaces, because air and hydraulic fluids act according to Pascal's Law that force and motion can be transmitted through them. Fluid or air will take the shape of its container.

CHARLES' LAW:

A gas reacts to a change in temperature much the same way as to changes in pressure. If the temperature increases, the pressure increases or the same ratio providing the volume stays the same. The principle of a gas's reaction to changes in temperature is called CHARLES' LAW.

BERNOULLI'S LAW:

The higher the speed of a flowing gas, the lower the pressure. If the speed decreases, the pressure increases and equally as the speed increases, the pressure decreases.

BOYLE'S LAW:

When the temperature stays the same, the volume of a given mass of gas varies inversely as its absolute pressure.

This means when we compress a gas, we push the molecules closer together. Then compressing a gas to half its original volume doubles the density of the molecules. It also doubles the rate that the molecules strike into the walls of the container, which doubles the gas pressure against the container walls. When a given mass of gas expands to twice its original volume, the molecules are farther apart and the number of times that the molecules stike the container wall is cut in half. This relationship is shown in the diagram below.

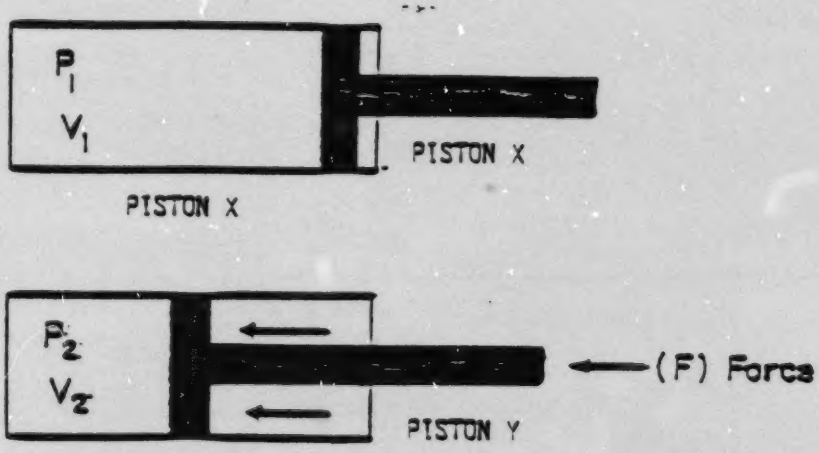
This relationship is a simple but very important formula which is used in analyzing pneumatic systems.

$$P1\ V1 = P2\ V2 \quad \text{or} \quad P2 = \frac{P1\ V1}{V2}$$

P1 is the initial pressure os psia
P2 is the final pressure in psia
V1 is the initial volume in cubic inches or cubic feet
V2 is the final volume in cubic inches or cubic feet

Starting with cylinder x having a volume V1 and a gas pressure of P1. When we place a force on the piston Y, the volume is decreased and the pressure os increased.

EXAMPLE: V2 is 1/2 V1, then ZP2 will be 2 times P1.



SELF-HELP EVALUATION #1

PRINCIPLES OF FLUID SYSTEMS

ANSWER THE FOLLOWING.....READ CAREFULLY.

1. FLUID SYSTEMS INCLUDE _____ AND _____ SYSTEMS.

2. Pneumatics advantages: (Select one that is inappropriate).

3. Gas pressure is _____ on all surfaces of a container.

4. A temperature rise causes gases to _____.

5. A gas pressure decrease causes a temperature _____.

6. Charles Law states:

7. Bernoulli's Law states:

8. Boyle's Law states:

INTERMEDIATE OBJECTIVE #2

Describe the methods of doing work in a fluid system.

LEARNING STEPS (Activities)

1. Read the information sheet cited in Resource #1 to discover work in fluid systems.
2. Complete the self-help evaluation cited in Resource #2 to determine your level of understanding.
3. Perform the activities cited in Resource #3 to develop math skills.
4. Read information sheet cited in Resource #4 to discover the work done by a piston.
5. Complete the self-help evaluation cited in Resource #5 to assure mastery of the intermediate objective.
6. Have your instructor review the self-help evaluation cited in Resource #5.
7. Proceed to the next Intermediate Objective.

RESOURCES

1. Information Sheet #3 pages 10 - 25 are entitled. "Work in fluid systems."
2. Self-help evaluation #2, page 26 entitled "Work".
3. Activity Sheet #1 page 28 to 38, entitled, "Work math skills."
4. Information Sheet #4 pages 41 - 43 are entitled "Work done by a piston"..
5. Self-help evaluation #3 is entitled, "Work in Fluid Systems", page 44.
6. See instructor.
7. The next Intermediate Objective guide starts on page 45.

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A TECHNICIAN TALKS ABOUT WORK

"I'm a technician in an automobile assembly plant. My job description includes being responsible for maintaining the plant's manufacturing equipment. Our plant recently has been rebuilt to use automated equipment for production work. This means that computer-controlled, mechanical conveyor systems take parts from one work station to another. Computers also control our machining equipment. Robots are used to fit parts together, weld auto bodies and spray-paint finishes. Heat lamps or ovens are used to dry the paint quickly and harden the finish.

"All this equipment, and much more, is combined to form our production system. This production system can turn out many automobiles when it's operating smoothly. I install and adjust the equipment to make it operate properly. When something goes wrong with the equipment, the production workers call on me to fix it.

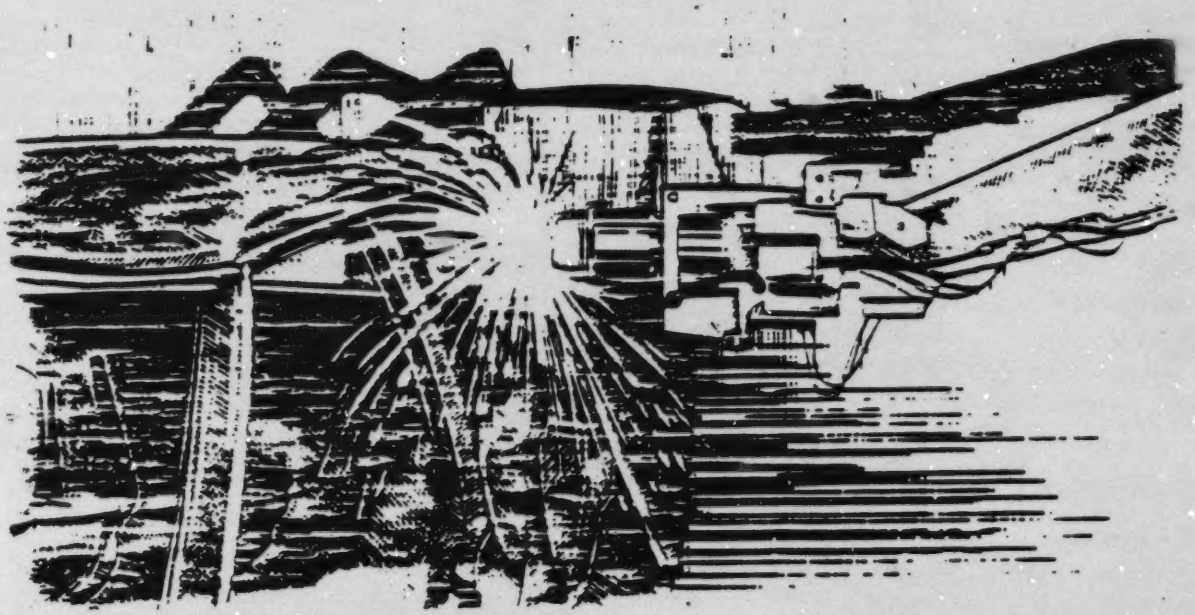


Fig. 2-1 Robot welding operation on auto assembly line.

"The first thing I have to do is troubleshoot the system to find the problem. Sometimes, it's a mechanical problem; other times, it's an electrical, computer or hydraulic problem. Whatever the problem, it's my job to get the system working again.

"If plant equipment doesn't do what it's supposed to, it isn't producing useful work. For instance, if a robot is supposed to move a part to another location but can't, then the robot hasn't done useful work. No matter how much force the robot exerts on the part, if the part hasn't moved (because it is jammed or something is in the way), then work hasn't been done. The same is true if an electrical force (voltage) is applied to a motor, but the motor doesn't turn. The voltage hasn't done useful work. Or if the pressure in the paint lines can't force the paint out (perhaps because the line is clogged), then the pressure hasn't done its work. In other words, things don't always accomplish work just because a force is applied; work is done when the force moves something.

"I like my job because I can see the results of my work. To me, work is getting something done. I can spend a lot of time and effort on a device, but if it doesn't do what it is supposed to do, I don't feel that I've done useful work. When I work on a device and help it run smoothly, both the device and I are accomplishing useful work. That's a good feeling, because this visible proof of my effort makes it obvious that what I do is important."

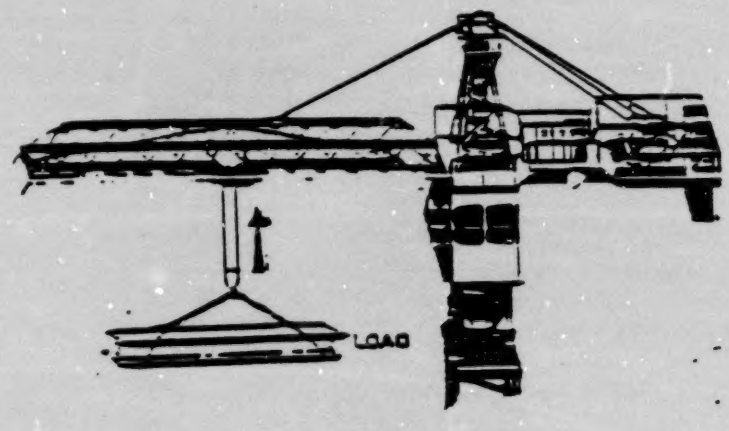
WHAT'S AHEAD?

In the technical sense, work is done only when a force or forcelike quantity causes something to move or change. First, we'll look at the easiest kind of work to understand, the mechanical work done when forces or torques cause objects to move. Then we'll look at work in other energy systems. In fluid systems, pressure does work by moving fluid. In electrical systems, voltage does work by moving charge. We'll study practical examples of work in mechanical, fluid and electrical energy systems. And we'll see how the concept of work helps us understand how one energy system affects another.

WHY IS WORK IMPORTANT IN TECHNOLOGY?

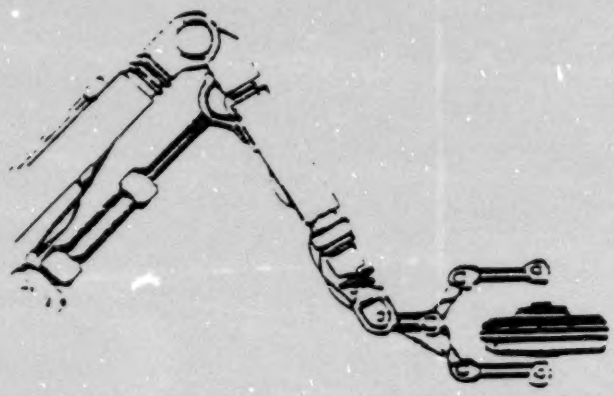
One definition of technology is "a collection of methods used to apply energy to do useful work." Useful work takes many forms. It may involve moving steel beams from one place to another, turning the crankshaft of a car, moving water through a pipe, or causing an electric charge to flow

through a wire. In any case, the work done must cause a specific change. The change may be as dramatic as lifting tons of steel--or as invisible as causing a tiny bit of charge to flow in a computer memory. But when work is done, something has to move or change. Complex technology is based on the technician's ability to apply forces and forcelike quantities to do whatever work needs to be done. In Figure 2-2, a crane does work by lifting a steel beam; a robot arm moves an engine part to the assembly line; air movement

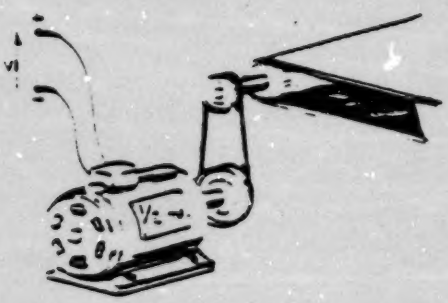


a. Crane lifts an I-beam.

b. Wind causes sleeve rotation.



c. Robot arm moves an engine part.



d. Electric motor drives a shaft.

Fig. 2-2 Work involves forces that cause movement.

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controlled by pressure difference in the atmosphere causes the blades of a windmill to turn; and voltage applied to a motor causes the shaft to rotate. These examples illustrate mechanical work being done.

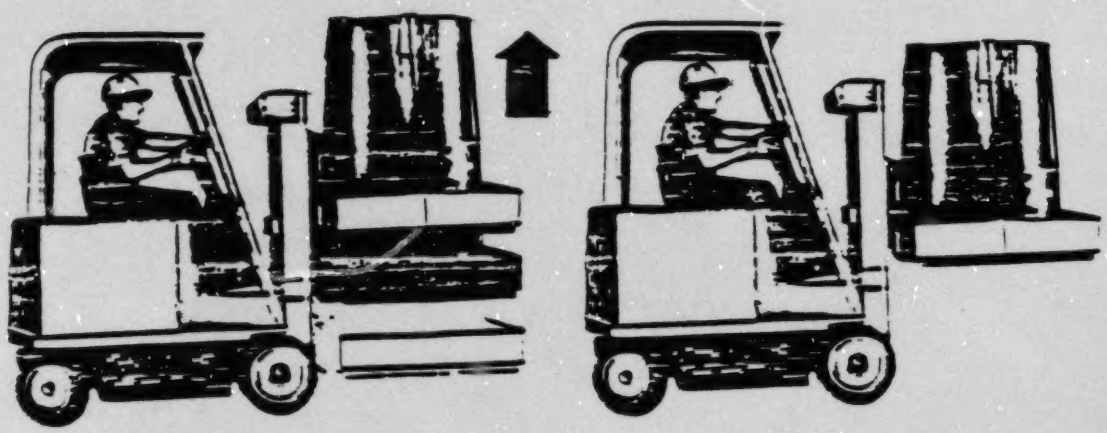
WHAT'S THE TECHNICAL DEFINITION OF WORK IN MECHANICAL SYSTEMS?

The technical definition of work in mechanical systems involves two parts: (1) an applied force that acts on an object, and, (2) movement of that object from one place to another. If you pick up a hammer and lift it over your head, you have done work on the hammer. You are applying a force that causes the hammer to move. If you hold a hammer over your head for a half-hour, without moving it, you do no work. You may get tired, but no work is done because there is no movement. How tired one becomes while applying a force has nothing to do with "work done"—in the technical sense. The amount of work done by a force acting on an object is defined as the force applied in the direction of motion times the distance the object moves while the force is acting. In equation form, work in a mechanical system is written as follows:

MECHANICAL WORK	=	FORCE APPLIED TO OBJECT	X	DISTANCE OBJECT MOVES

Figure 2-3a shows a forklift doing work by lifting a heavy drum. Figure 2-3b shows the forklift holding the drum in a fixed position by applying a force; but in this case, the forklift is doing no work.

Another type of mechanical work is done when a torque causes something to rotate. Examples of rotating objects on which work is done include the wheels of a car, a record player, a power drill for drilling holes, the blades on a helicopter and the gears in an automatic transmission. In these examples, the work done is the forcelike quantity, torque, times the angle



a. Forklift moves a load.

b. Forklift holds a load.

Fig. 2-3 A forklift does work only only when it moves something.

through which the object rotates while the torque is applied. In equation form, this activity is expressed as follows:

MECHANICAL WORK	=	TORQUE APPLIED TO OBJECT	x	ANGLE THROUGH WHICH OBJECT TURNS

WHAT ABOUT THE CONCEPT OF WORK IN OTHER ENERGY SYSTEMS?

As you might expect, the concept of work also applies to change produced by forcelike quantities in other energy systems. In a fluid system, a pressure difference causes a volume of liquid or gas to flow from one place to another. The work done in moving the fluid is the product of the pressure difference times the volume of fluid moved. This is written as follows:

FLUID WORK = PRESSURE DIFFERENCE x VOLUME MOVED

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In an electrical system, voltage causes charge to move from one place to another. The work done in moving the charge is the product of the voltage and the amount of charge moved. This is written as follows:

ELECTRICAL WORK = VOLTAGE x CHARGE MOVED

Work, then, has been defined as a "force times a distance." Using this definition, how does "pressure difference times volume moved" (work in a fluid system) or "voltage times charge moved" (work in an electrical system) involve a "force" and a "distance?"

In fluid systems, pressure causes fluids to move. Since pressure is a force per unit area, force is involved. Since fluid moves from one place to another, under the push of pressure, distance is also involved. So "pressure difference x volume moved" in fluid systems is a useful way to calculate "work done." The "applied force" and the "distance moved" are still involved. They are just expressed in a different form.

What about "voltage difference times charge moved?" How does this relate to "force times distance?" This question is not as easy to answer. But if you could see what happens in DC electrical circuits, you would see that electrical forces push electrons through the circuit, from the negative battery terminal back to the positive battery terminal. On a microscopic scale, then, billions and billions of electrons are pushed by electrical forces. So forces are involved. As they're pushed, the electrons move from one place to another. So distance is involved. It turns out that the equation "voltage times charge moved" is correct--and much easier to use--than "force times distance."

WORK AS A UNIFYING CONCEPT

When the basic concept of work is applied to different systems, it unifies our understanding of what happens in each system. Thus, we learn that work is a concept that applies in mechanical, fluid and electrical systems. Work is, therefore, a unifying concept that helps us understand mechanical, fluid and electrical systems better.

In Unit 1, we learned about force as a unifying concept. We learned that real forces—and forcelike quantities—always cause things to move or change. We learned that forces move objects, that torques cause rotation, that pressure moves fluids, that voltage moves charge. We used these analogies to expand and strengthen our understanding of what a force is and does.

In Unit 2, "Work," we study another unifying concept. We've already learned that work in mechanical, fluid and electrical energy systems can be expressed in equation form. These equations are written as follows:

MECHANICAL WORK (LINEAR MOTION)	= FORCE APPLIED x DISTANCE MOVED
MECHANICAL WORK (ROTATIONAL WORK)	= TORQUE APPLIED x ANGLE MOVED THROUGH
FLUID WORK	= PRESSURE x VOLUME MOVED
ELECTRICAL WORK	= VOLTAGE x CHARGE MOVED

We can write ONE equation for work that serves as a pattern for the four equations above. This pattern equation, given below, is a UNIFYING equation for the concept of work.

WORK (UNIFYING)	= FORCE OR FORCELIKE QUANTITY	x	DISTANCE OR QUANTITY MOVED

The force—or forcelike quantity—causes a change in each system. The "distance or quantity moved" is a description of something that moves or changes while work is being done. We sometimes refer to the "distance or quantity moved" as the "displacementlike quantity."

MAIN IDEAS

- Fluids flow naturally from high-pressure to low-pressure regions.
- Fluid systems are either open-type or closed-type.
- Open-type systems move fluids, but do not retain or recirculate fluids.
- Closed-type systems retain and recirculate fluids.
- Work occurs in a fluid system when fluid pressure difference causes liquids or gases to move.

$$W = (\Delta P) \times V$$

- Work occurs in a fluid system when fluid pressure displaces a fluid volume.

$$W = P \times (\Delta V)$$

- Fluid systems interact with mechanical and electrical systems to produce useful work.

DISCUSSION

In a fluid system, work is done whenever a pressure difference causes liquids or gases to move. Winds blow because air moves naturally from high-pressure regions to low-pressure regions. Work is done by pressure differences that move air as we breathe. When we inhale, we expand our chest cavity and create a region of low pressure inside our lungs. A higher pressure region outside then acts to move air in to fill our lungs. When we exhale, body muscles decrease our lung volume. This increases the air pressure in the lungs and forces the air out. As Figure 2-9 shows, pressure differences cause movement within a fluid system.

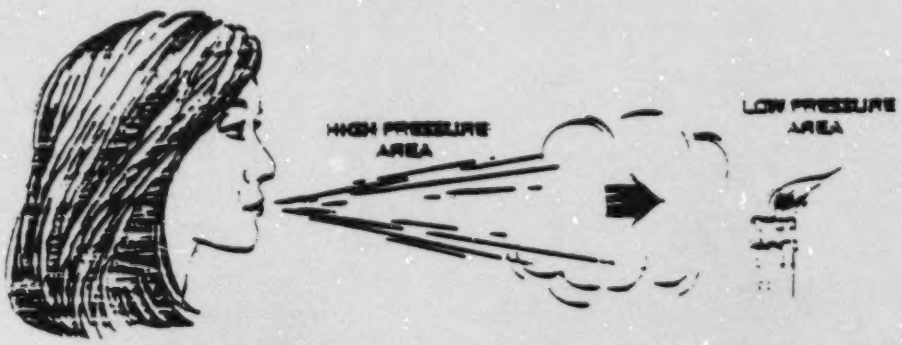

Fig. 2-9 Pressure difference causes fluid motion.

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OPEN AND CLOSED FLUID SYSTEMS

There are two types of fluid systems—open and closed. A closed fluid system is designed to retain and recirculate the fluid. Examples of closed fluid systems include a hydraulic jack, a hydraulic brake system and the body's circulatory system. An open fluid system moves fluids, but does not retain and recirculate the fluids throughout the system. A city water system, an irrigation system or a fire truck water system are examples of open fluid systems. Examples of open and closed fluid system are shown in Figure 2-10.

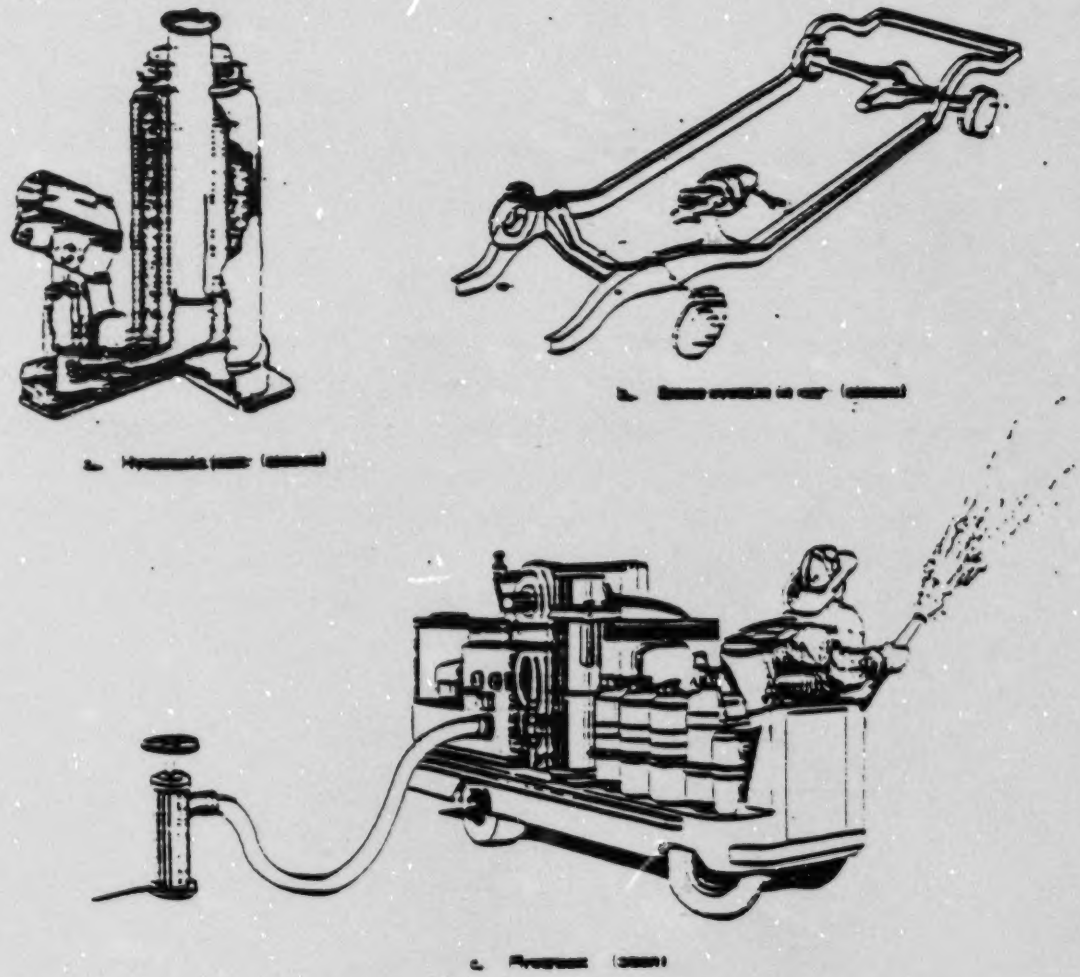

Fig. 2-10 Open and closed fluid systems.

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BASIC HYDRAULIC POWER SYSTEM

A hydraulic power system is used widely in industry and transportation. The basic system, shown in Figure 2-11, is a closed system. It is used to do mechanical work on a load attached to the working piston. Let's examine the different parts and see how they operate together as a system.

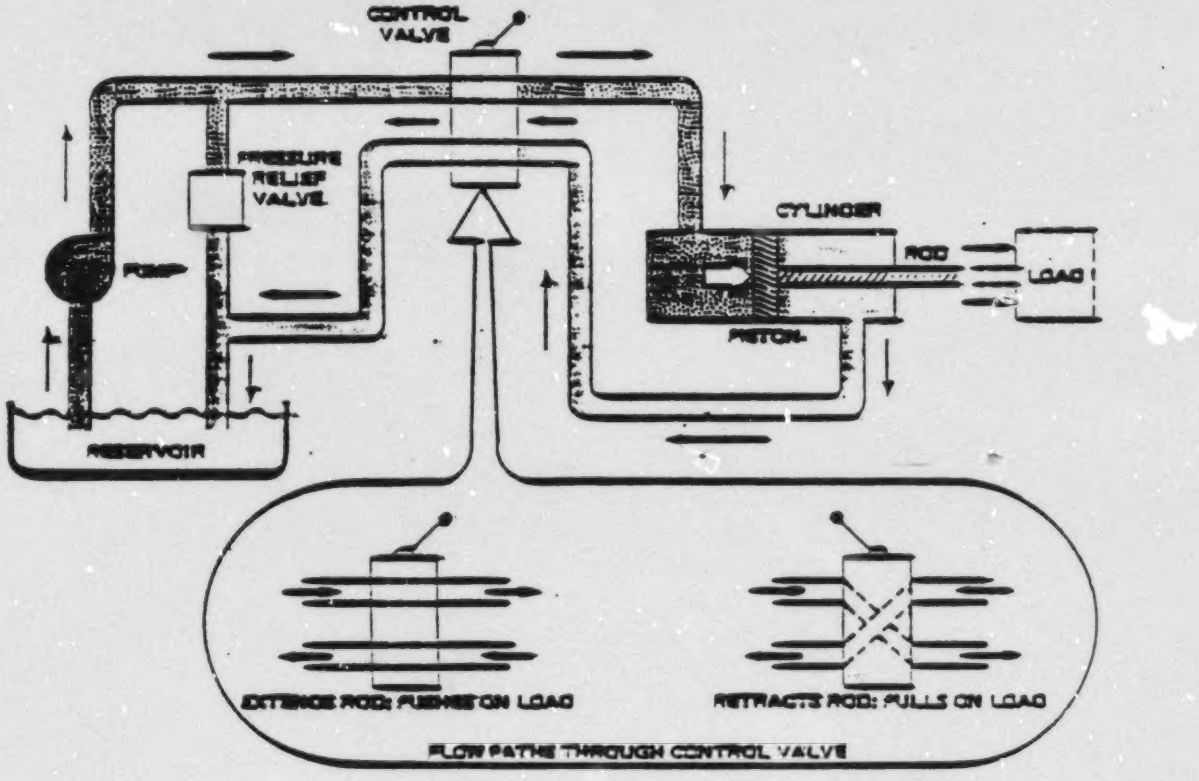

Fig. 2-11 Simple fluid power system.

The pump draws liquid from the reservoir, creates a pressure difference and forces liquid through the pipes under pressure. The pump is driven by a rotating shaft that has been connected to a motor. The control valve is used to direct the liquid to the cylinder to either push or pull on the load. In one position, high pressure liquid flows directly to the left side of the piston, creating a force on the piston that causes the rod to extend or push on the load. (This is the arrangement shown in Figure 2-11.)

In the other position, high-pressure liquid flows directly to the right side of the piston, causing the rod to retract or pull on the load. (Details

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of the flow through the control valve are shown in Figure 2-11 for each position of the valve.) In either position, after moving the piston in the cylinder, the liquid is forced out of the cylinder and directed back to the reservoir.

In a third position (not shown), the control valve blocks flow to the cylinder and holds the piston in place. When the control valve blocks the flow, the pressure-relief valve opens automatically. This action allows the liquid in the pump line to flow directly back to the reservoir. This protects the system from damage caused by overpressures in the lines.

WORK DONE IN FLUID SYSTEMS

In mechanical systems, when a force moves an object through some distance, work is done. This mechanical work has been defined as "force times distance." Likewise, in a fluid system, whenever pressure causes a fluid to move, work is done. This type of work is defined in terms of the two equations that follow:

$$\text{WORK} = \frac{\text{PRESSURE}}{\text{DIFFERENCE}} \times \frac{\text{VOLUME MOVED FROM HIGH PRESSURE TO LOW PRESSURE}}{}$$

$$W = (\Delta P) \times V$$

$$\text{WORK} = \text{PRESSURE} \times \text{FLUID VOLUME DISPLACED}$$

$$W = P \times (\Delta V)$$

For example, consider the work done by a pump that lifts water from a lake or well to a tank through a vertical distance of "H" feet. (See Figure 2-12.) This type of work is calculated best by using the first equation, $W = (\Delta P) \times V$. The pump moves a certain volume of water (V) through a pressure difference (ΔP). The pressure at the top of the discharge pipe is equal to atmospheric pressure.

The pressure at the bottom, at the inlet pipe, is equal to atmospheric pressure, plus the pressure that comes from the column of water "H" feet high. The pressure difference, from bottom to top, is then equal to the pressure of the water column of height H.

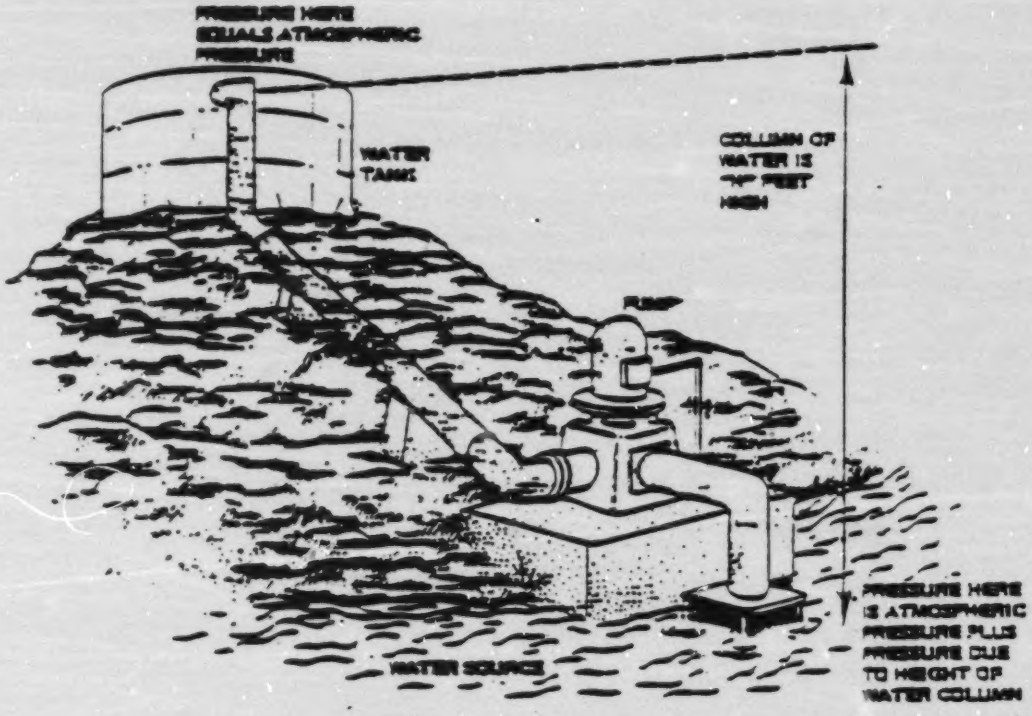
PRESSURE HERE EQUALS ATMOSPHERIC PRESSURE
WATER TANK
COLUMN OF WATER IS "H" FEET HIGH
PUMP
PRESSURE HERE IS ATMOSPHERIC PRESSURE PLUS PRESSURE DUE TO HEIGHT OF WATER COLUMN
WATER SOURCE

Fig. 2-12 Pump does fluid work in lifting water.

Water systems in rural areas and small cities maintain water pressure by storing water in large tanks 50 to 150 feet above the ground. The tank is filled by pumping water into it from a lake or a well. In Example 2-7, we use the work equation $W = (\Delta P) \times V$ to calculate how much work a water pump must do to fill a 500-cubic-foot tank that is 150 feet above a lake.

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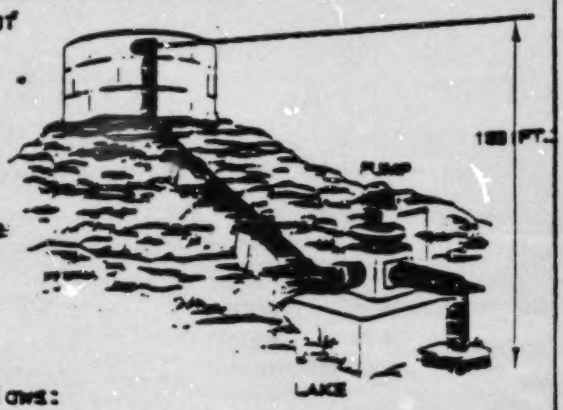
EXAMPLE 2-F: WORK DONE BY PUMP TO FILL A TANK

Given: Water tank with a volume of 500 cubic feet (500 ft^3), located 150 feet above water level in a lake. A pump is used to lift the water from the lake to the tank.



Find: Work done by pump to fill the tank.

Solution: Use the equation that follows:

Work Done = (Pressure Difference) x (Volume Moved)

$W = (\Delta P) \times V$

Step 1: Find (ΔP).

Pressure difference (ΔP) is equal to the pressure of the column of water 150 feet high. From Unit 1, "Force," we learned that this pressure is:

P = (Weight density) x height; (Weight density of water is 62.4 lb/ft^3.)

$$P = 62.4 \frac{lb}{ft^3} \times 150 \text{ ft} \qquad \left(\frac{lb}{ft^3} \times ft = \frac{lb}{ft^2}\right)$$

$$P = (62.4 \times 150) \frac{lb}{ft^2}$$

$$P = 9360 \text{ lb/ft}^2 \qquad \text{(This is } \Delta P\text{.)}$$

Step 2: Find V.

V is the volume of water moved from the lake to the water tank. It is given as 500 ft^3.

Step 3: Now substitute known values for (ΔP) and V in the equation $W = (\Delta P) \times V$ to find the work done.

$W = (\Delta P) \times V$

$$W = \left(9360 \frac{lb}{ft^2}\right)(500 \text{ ft}^3) \qquad \left(\frac{lb}{ft^2} \times ft^3 = ft \cdot lb\right)$$

$W = 4,680,000$ ft·lb

The work done by the pump to move 500 cubic feet of water a distance of 150 feet to fill the tank is 4,680,000 ft·lb.

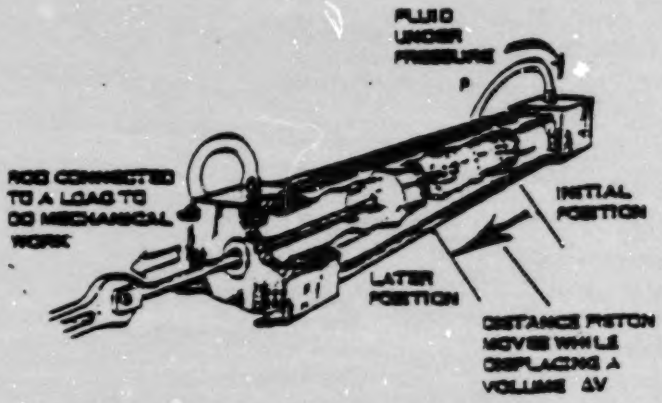

FLUID UNDER PRESSURE P
ROD CONNECTED TO A LOAD TO DO MECHANICAL WORK
INITIAL POSITION
LATER POSITION
DISTANCE PISTON MOVES WHILE DISPLACING A VOLUME ΔV

Fig. 2-13 Work done by a hydraulic cylinder.

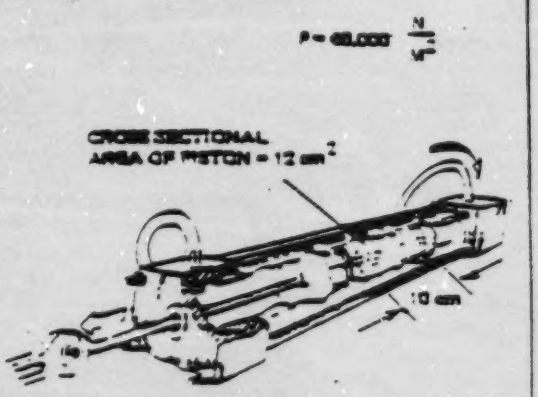
The other equation for fluid work, $W = P \times (\Delta V)$, is used, for example, in calculating the work done by a piston in a hydraulic cylinder. (See Figure 2-13.) Here, the pressure (P), acting on the piston, moves the piston. This movement displaces a volume (ΔV) of fluid.

Heavy-duty robots in industry are used to move large objects or exert strong forces. Such robots use hydraulic cylinders to get the job done. Most hydraulic cylinders (such as the one in Figure 2-13) are made up of a hollow cylinder, a piston and fluid under pressure. Often the fluid is oil, delivered under pressure to the chamber on one side of the piston. The oil pushes against the piston, causing it to move. The other end of the piston is connected to a load. As the piston moves, it moves the load, doing useful mechanical work. Example 2-6 shows how work done by a hydraulic cylinder is calculated.

EXAMPLE 2-6: WORK DONE BY A HYDRAULIC CYLINDER

Given: A hydraulic cylinder moves a piston 10 centimeters while pushing on a mechanical load. The fluid pressure on the piston face is 80,000 N/m^2. The area of the piston face (cross-sectional area of the cylinder) is 12 cm^2.

Find: Work done by the hydraulic cylinder while moving the piston 10 cm.



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Solution: Use the equation that follows:

Work Done = (Pressure) x (Volume Displaced)

$W = P \times (\Delta V)$

Step 1: Find P.

The pressure P is given as 80,000 N/m^2.

Step 2: Find (ΔV).

The volume of fluid displaced as the piston moves 10 cm is the same as the volume of a cylinder of cross-sectional area 12 cm^2 and length 10 cm.

V = Area x Length

$V = 12\ cm^2 \times 10\ cm$ $\quad (1\ cm^2 \times 1\ cm = 1\ cm^3)$

$V = 120\ cm^3$ (This is ΔV in cm^3.)

Convert ΔV in cm^3 to ΔV in m^3.

$$\Delta V = 120\ cm^3 \times \frac{1\ m^3}{1{,}000{,}000\ cm^3} = 0.00012\ m^3 \quad (\text{Cancel } cm^3\text{'s.})$$

$\Delta V = 0.00012\ m^3$

Step 3: Now substitute known values for P and (ΔV) in the equation $W = P \times (\Delta V)$ to find the work done.

$W = P \times (\Delta V)$

$$W = \left(80{,}000\ \frac{N}{m^2}\right) \times (0.0012\ m^3) \qquad \left(\frac{1}{m^2} \times \frac{m^3}{1} = m\right)$$

$W = 9.6\ N\text{-}m$

The hydraulic cylinder does 9.6 N-m of work while moving the load attached to the piston a distance of 10 cm.

EXAMPLES OF WORK IN FLUID SYSTEMS

We have studied work done in an open fluid system (filling a city water tank) and a closed fluid system (hydraulic cylinder). We also have studied fluid work done when the intended outcome of the work is (a) to move fluid from one location to another (filling the water tank), and (b) to do some type of mechanical work (hydraulic cylinder).

Useful fluid work is often done--in open or closed fluid systems--simply to move fluids from one location to another. Examples of open fluid systems that do work include:

- movement of natural gas through pipes from supplier to user.
- movement of oil through pipes from wells to refineries (Alaskan pipeline).
- movement of fuel in an automobile from gas tank to carburetor.
- movement of air through ducts in air-conditioning systems.
- movement of water in fire truck pumpers from water hydrants to fire hoses.
- movement of paint in paint-spraying systems.
- movement of water and steam in a coal-fired power plant.
- movement of water from lakes or wells to storage tanks.
- movement of air through compressors in jet engines.

Useful work is also done in closed fluid systems to provide mechanical work. Examples of this type of fluid work include:

- operation of brakes in an automobile braking system.
- use of hydraulic jacks to lift heavy loads.
- use of hydraulic cylinders to push or pull on mechanical loads.

If we look back at the basic fluid power system shown in Figure 2-11, we can see that three different forms of work are involved in the operation of the entire system. Electrical work is done on the motor to operate the pump. The pump, in turn, does fluid work on the liquid to move it through the system. The moving liquid, under pressure, does mechanical work on the piston and load. It is often true, as it is even in this fairly simple system, that several forms of work are being done at the same time. That is why a good understanding of work in mechanical, fluid and electrical systems is important--and it is also why the general idea of WORK as a unifying concept is helpful to our understanding.

SELF-HELP EVALUATION
"WORK"

The following exercises review the main ideas and definitions presented in this subunit, "Work in Fluid Systems." Complete each question as indicated.

1. When work is done by a pump to raise water through a pressure difference, the _____ is multiplied by the pressure difference. (Circle the correct answer.)
   a. fluid weight moved
   b. fluid volume moved
   c. distance fluid moves
   d. weight density of fluid

2. When a moving piston does work in a hydraulic cylinder, the pressure exerted by the piston is multiplied by _____. (Circle the correct answer.)
   a. area of the piston face
   b. fluid volume displaced
   c. weight density of the fluid

Each fluid system in the left-hand column below is classified as either an open fluid system or a closed fluid system. In each of the blanks provided, place the appropriate letter representing the type of system from the right-hand column.

3. ___ city water system
4. ___ auto fuel system
5. ___ auto brake system
6. ___ fire department pumper truck
7. ___ hydraulic jack

a. closed fluid system
b. open fluid system

8. The purpose of pumps in fluid systems is to _____. (Circle the correct answer.)
   a. draw fluid from a reservoir
   b. force fluid through a pipe
   c. create a pressure difference
   d. a and b only
   e. a, b and c

9. The work required to lift water from a lake to a tank above the lake is given by $W = (\Delta P) \times V$. To find the pressure difference (ΔP), the _____ _____ of the water must be known, as well as the height (h) of the lift. (Fill in the blank.)

10. To push a box onto a conveyor belt with the shaft of a hydraulic cylinder, a motor-driven pump pressurizes the fluid that operates the piston. This is an example of the general idea of _____ as a unifying concept. (Fill in the blank.)

11. A pump lifts 2 cubic meters of water through a pressure difference of 200,000 N/m^2. The fluid work done by the pump is: (Circle the correct answer.)

    a. 400,000 N/m
    b. 400,000 N-m
    c. 100,000 N/m
    d. 100,000 N-m

12. A hydraulic cylinder displaces 0.25 ft^3 of oil while the piston moves a distance of 1 ft. The pressure on the face of the piston is 60 lb/ft^2. The work done by the hydraulic cylinder while moving the piston 1 ft is: (Circle the correct answer.)

    a. 60 ft-lb
    b. 60 ft/lb
    c. 15 ft-lb
    d. 240 ft-lb

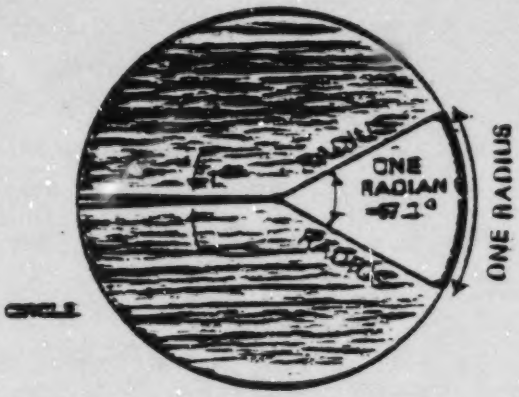
ACTIVITY SHEET #1
WORK MATH SKILLS

ACTIVITY 1: MEASURING ANGLES IN RADIANS

APPARATUS: For this activity, you will need a protractor and a hand calculator.

DISCUSSION

A. The radian is a unit of angle measure. It is like a degree, only much larger. It is equal to 57.3°. The radian is defined in terms of a piece of a circle. An angle of one radian cuts off an arc on the circle equal to the radius of the circle, as shown below.



B. In terms of revolutions, degrees and radians, we have the following relationships:

1 revolution = 360° (The symbol "°" stands for degree.)

1 revolution = 6.28 radians (abbreviated "rad")

1 radian = 57.3°

C. When changing degrees to radians, multiply angle in degrees by the fraction, $\left(\frac{1 \text{ radian}}{57.3 \text{ degrees}}\right)$. This fraction is equal to <u>one!</u>

Example: Change 90° to radians.

$$(90 \text{ degrees}) \times \left(\frac{1 \text{ radian}}{57.3 \text{ degrees}}\right) = \underline{\underline{1.57 \text{ rad}}} \quad \text{(Cancel degrees.)}$$

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Example: Change 287° to radians.

$$(287 \text{ degrees}) \times \left(\frac{1 \text{ radian}}{57.3 \text{ degrees}}\right) = 5.01 \text{ rad} \quad \text{(Cancel degrees.)}$$

D. When changing revolutions to radians, multiply angle in revolutions by the fraction $\left(\frac{6.28 \text{ radians}}{\text{revolution}}\right)$. This fraction is equal to one!

Example: Change 2.5 revolutions to radians.

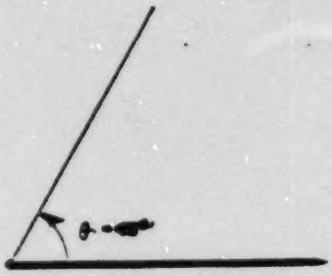
$$(2.5 \text{ rev}) \times \left(\frac{6.28 \text{ rad}}{\text{rev}}\right) = 15.7 \text{ rad} \quad \text{(Cancel revs.)}$$

Example: Change 10 revolutions to radians.

$$(10 \text{ rev}) \times \left(\frac{6.28 \text{ rad}}{\text{rev}}\right) = 62.8 \text{ rad} \quad \text{(Cancel revs.)}$$

E. Measure the following angles with a protractor, and change angle in degrees to angle in radians.

Example:



θ measured = 60°

θ in radians is equal to:

$$60° \times \left(\frac{1 \text{ rad}}{57.3°}\right) = 1.05 \text{ rad}$$

Example:

θ measured = 150°

θ in radians is equal to:

$$150° \times \left(\frac{1 \text{ rad}}{57.3°}\right) = 2.62 \text{ rad}$$

PRACTICE EXERCISES FOR ACTIVITY 1

Problem 1: Change each angle in degrees to an angle in radians.

(Remember, 1 radian = 57.3°.)

a. 30° =

b. 57.3° =

c. 360° =

Problem 2: Change revolutions to angle in radians.

(Remember, 1 revolution = 6.28 radians.)

a. 0.5 revolutions =

b. 5 revolutions =

c. 3.2 revolutions =

Problem 3: Draw an angle of 85° with a protractor. What is the angle in radians?

ACTIVITY 2: WORKING WITH PERCENTS

APPARATUS: For this activity, you will need a hand calculator.

DISCUSSION

The word "percent" means "one hundredth." The word "percentage" means "the part of a whole expressed in hundredths."

A. To change a fraction or whole number to a percent, first write the fraction as an equal number of hundredths. This number, with percent (or %) written after it, is the desired answer. For example:

one-half = 50 hundredths = 50 percent or 50%
one-fourth = 25 hundredths = 25 percent or 25%
one (whole) = 100 hundredths = 100 percent or 100%
two (two wholes) = 200 hundredths = 200 percent or 200%
two-fifths = 40 hundredths = 40 percent or 40%

8. To change a decimal to a percent, simply multiply the decimal by 100 and attach the "%" sign. For example:

   To change 0.25 to a percent,
   0.25 x 100 = 25%; therefore, 0.25 = 25%.

   To change 1.20 to a percent,
   1.20 x 100 = 120%; therefore, 1.20 = 120%.

PRACTICE EXERCISES FOR ACTIVITY 2

Problem 1: Change each of the following fractions to numbers written as a percent.

a. three-fourths (3/4) =
b. one-fifth (1/5) =
c. two-tenths (2/10) =
d. nine-tenths (9/10) =
e. one and one-half (1 1/2) =

Problem 2: Change each of the following decimals to numbers written as a percent.

a. 0.33 =
b. 0.95 =
c. 0.10 =
d. 1.50 =
e. 0.50 =

ACTIVITY 3: SUBSTITUTING IN FORMULAS

APPARATUS: For this activity, you will need a hand calculator.

DISCUSSION

When a force does work on a machine, such as a pulley or a winch, we call this input work or WORK IN. When the machine does work on something else, such as lifting a weight or hauling a load, we call this output work or WORK OUT. If there is no friction present in any of the turning parts of the machine, WORK OUT = WORK IN. However, for most machines, friction is

present and WORK OUT is less than WORK IN. The percent efficiency of this machine is given by the equation that follows:

$$\% \text{ EFF} = \left(\frac{\text{WORK OUT}}{\text{WORK IN}}\right) \times 100$$

This equation is used to solve a problem in the example below.

EXAMPLE A: CALCULATING EFFICIENCY OF A PULLEY SYSTEM

Given: A block-and-tackle pulley system to lift a weight. The pulley system does 980 newton-meters of work (WORK OUT) to lift a weight. To cause the pulley system to operate, 1000 newton-meters of work (WORK IN) are required.

Find: Efficiency of the pulley system.

Solution: Step 1: Write down the formula for efficiency.

$$\% \text{ EFF} = \left(\frac{\text{WORK OUT}}{\text{WORK IN}}\right) \times 100$$

Step 2: Identify what is given and what needs to be found.

Given: WORK OUT = 980 N-m

WORK IN = 1000 N-m

Find: % EFF

Step 3: Substitute given values for WORK IN and WORK OUT in the formula. Include both the numerical value and the units, as follows:

$$\% \text{ EFF} = \left(\frac{\text{WORK OUT}}{\text{WORK IN}}\right) \times 100$$

$$\% \text{ EFF} = \left(\frac{980 \text{ N-m}}{1000 \text{ N-m}}\right) \times 100 \qquad \text{(Cancel newton-meters.)}$$

Step 4: Use a calculator to perform the calculation. Write out the answer.

% EFF = 98%

Conclusion: The pulley system is 98% efficient. The difference between 100% and 98% is the work done (wasted) to overcome the friction in the moving wheels of the pulley system.

PRACTICE EXERCISES FOR ACTIVITY 3

Given the formula % EFFICIENCY = $\left(\frac{\text{WORK OUT}}{\text{WORK IN}}\right)$ x 100, solve each system listed below.

Problem 1: Calculate the % efficiency for a block and tackle lifting a load of 600 pounds under the following conditions:

WORK OUT = 1200 ft·lb

WORK IN = 1400 ft·lb

Problem 2: Calculate the % efficiency for a winch hauling in a load of 1000 newtons under the following conditions:

WORK OUT = 3000 N-m

WORK IN = 3150 N-m

Problem 3: Calculate the % efficiency for a "frictionless" pulley system that raises an automobile under the following conditions:

WORK OUT = 3000 ft·lb

WORK IN = 3000 ft·lb

REARRANGING SYMBOLS IN EQUATIONS TO SOLVE FOR UNKNOWNS

DISCUSSION

A. Equations and formulas are used to express a relationship between several physical quantities. Equation 1, which relates the concept of work, force and distance, shows this relationship as follows:

WORK = FORCE APPLIED x DISTANCE MOVED Equation 1

This equation provides a means of determining the value of one physical quantity if the numerical values of the other two are known. Frequently, equations are written with symbols rather than words. Thus, Equation 1 becomes simplified by using the following symbols:

$W = F \times D$ or $W = FD$ Equation 2

where: W = work (newton-meters or foot-pounds)
F = force (newtons or pounds)
D = distance (meters or feet)

B. A technician often must rearrange symbols in an equation to obtain a different form of the same equation. Thus, the equation $P = F/A$ can be rearranged to yield $F = P \times A$ or $A = F/P$. Each of the three forms is correct. Sometimes, one is more useful than the other.

C. To "solve" an equation means to isolate one symbol in the equation. To accomplish this isolation, certain mathematical operations are performed, identically, on both sides of the equation. Any operation performed on one side of the equation always is performed on the other side. Therefore, care must be taken to do the following:

- Add or subtract the same quantity on both sides of an equation.
- Multiply or divide both sides by the same quantity.

Study the examples that follow. They show how to isolate a certain symbol by rearranging the given equation.

EXAMPLE A: REARRANGING SYMBOLS IN W = F x D TO ISOLATE F

Given: $W = F \times D$

Find: F

Solution: Step 1: In rearranging the equation $W = F \times D$ to isolate or "solve" for F, start with the given equation, $W = F \times D$.

Step 2: Divide both sides by D to isolate F.

$\frac{W}{D} = \frac{F \times D}{D}$ (The D's cancel out on the right side.)

Step 3: Rewrite the equation with the D's on the right side removed.

$\frac{W}{D} = F$ (F has been isolated.)

Step 4: Reverse the order of the equation so that F is on the left.

$F = \frac{W}{D}$

The equation $W = F \times D$ has been "solved" for F. The symbol, "F," has been isolated and the correct equation is $F = \frac{W}{D}$.

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EXAMPLE B: REARRANGING SYMBOLS IN $W = T \times \theta$ TO ISOLATE θ

Given: $W = T \times \theta$

Find: θ

Solution: Step 1: To solve for θ, start with the given equation, $W = T \times \theta$.

Step 2: Divide both sides by T to isolate θ.

$\frac{W}{T} = \frac{T \times \theta}{T}$ (The T's cancel out on the right side.)

Step 3: Rewrite the equation with the T's on the right side removed

$\frac{W}{T} = \theta$ (The symbol, "θ," has been isolated.)

Step 4: Rearrange with isolated symbol θ on the left side.

$\theta = \frac{W}{T}$

The equation $W = T \times \theta$ has been "solved" for θ. The symbol, "θ," has been isolated and the correct equation is $\theta = \frac{W}{T}$.

Using Examples A and B as a guide, solve the following four equations by isolating the symbol indicated.

Equation 1: Given: $W = F \times D$

Find: D

Solution:

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Equation 2: Given: $W = T \times \theta$
Find: T
Solution:

Equation 3: Given: $W = (\Delta P) \times V$
Find: ΔP
Solution:

Equation 4: Given: $W = P \times (\Delta V)$
Find: ΔV
Solution:

SUBSTITUTING IN FORMULAS

DISCUSSION

A. Care always must be taken to substitute correct numbers and units for known symbols in an equation. Only then can the number and unit of the unknown (isolated) symbol be calculated correctly.

EXAMPLE C: SUBSTITUTING IN THE WORK EQUATION W = F x D TO FIND FORCE

Given: $W = F \times D$ Where: $W = 10$ N-m
$D = 2$ m

Find: F

Solution: Step 1: Solve for F. (See Example A.) This gives the equation,
$F = W/D$.

Step 2: Substitute given numerical values—with units—for W and D. ($W = 10$ N-m and $D = 2$ m.)

Step 3: Then, $F = \frac{10 \text{ N-m}}{2 \text{ m}}$. (Cancel m's.)

Step 4: Dividing the numbers and cancelling out meters gives $F = 5$ N. (The force is 5 newtons.)

8. A good check to make sure that the equation you're using is set up correctly is to check units. Check the units of each physical quantity in the equation. See if they're correct and are equal overall on either side of the equation. Example D shows how to do this.

EXAMPLE D: CHECKING ACCURACY OF EQUATION BY CHECKING UNITS

Given: $W = F \times D$

Find: F

Solution: Step 1: Rewrite the given equation so F is at the left of the equal sign and everything else is at the right. (Refer to Example A if necessary.)

$F = \frac{W}{D}$

Step 2: Substitute units for F, W and D in this equation.

$\text{newtons} = \frac{\text{newton-meters}}{\text{meters}}$ (Cancel meters.)

This leaves newtons = newtons. Units "check out."

Therefore, the equation has been set up correctly.

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In the problems that follow, you must:

- Isolate the required physical quantity to derive a new formula.
- Substitute the numerical values of the known physical quantities into the formula.
- Check the formula by checking units, as in Example D.
- Solve for the unknown quantity.

*Problem 1:

Given: $T = F \times L$, where: $T = 20$ lb·ft

$F = 5$ lb

Find: L

Solution: Step 1: Rearrange equation to isolate L.

$T = F \times L$

Step 2: Divide both sides of the equation by F.

$\frac{T}{F} = \frac{F \times L}{F}$ (F's cancel out on right side of equation.)

$\frac{T}{F} = L$ (L has been isolated.)

Step 3: Reverse sides of equation to put L on the left.

$L = \frac{T}{F}$

Step 4: Substitute known values for F and T.

$L = \frac{T}{F}$, where $T = 20$ lb·ft and $F = 5$ lb

$L = \frac{20 \text{ lb·ft}}{5 \text{ lb}}$ (Cancel lb units.)

$L = 4$ ft

Step 5: Check units in equation.

$L = \frac{T}{F}$, where L is in ft; T is in lb·ft; F is in lb.

Therefore, $\text{ft} = \frac{\text{lb·ft}}{\text{lb}}$ (Cancel lb units.)

ft = ft (Units check; equation is correct.)

*This problem has been solved for you. Follow through the solution to make sure you understand each step.

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Problem 2:

Given: $W = T \times \theta$, where: $\theta = 6.28$ rad
$W = 62.8$ ft·lb

Find: T

Solution: Step 1: Isolate T in the equation.

Step 2: Reverse sides of equation to put T on the left.

Step 3: Substitute known values for W and θ, and solve for T.

Step 4: Do unit check on equation.

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DISCUSSION

In hydraulic cylinders, a liquid under pressure moves a piston. The piston, in turn, moves a mechanical load and does useful work. Similarly, in steam engines, the steam, under high pressure, moves a piston back and forth, doing useful work. In gasoline engines, a piston does work on a mixture of air and gasoline vapor while it compresses the gas into a smaller volume. Figure 1 shows a piston doing work on the gas mixture in an automobile cylinder during the "compression stroke" for that cylinder.

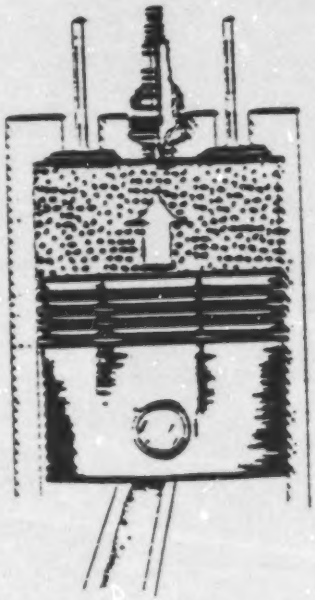

Fig. 1 Piston does work during the gas-compression stroke.

Figure 2 shows a picture of a piston in a steam engine. Steam is admitted alternately, first on one side of the piston, then on the other. This causes the piston to move back and forth in a reciprocating manner.

Reciprocating motion (back and forth) is often converted to circular motion to turn a flywheel for useful purposes.

In this laboratory, we'll study the work done by a piston while it compresses a gas. We will use a simple mock-up of a piston and cylinder arrangement that "squeezes" gas into a smaller volume. We'll find the WORK DONE by using the equations $W = F \times D$ (Work = Force times Distance) and $W = P \times \Delta V$ (Work = Pressure times Volume Displaced).

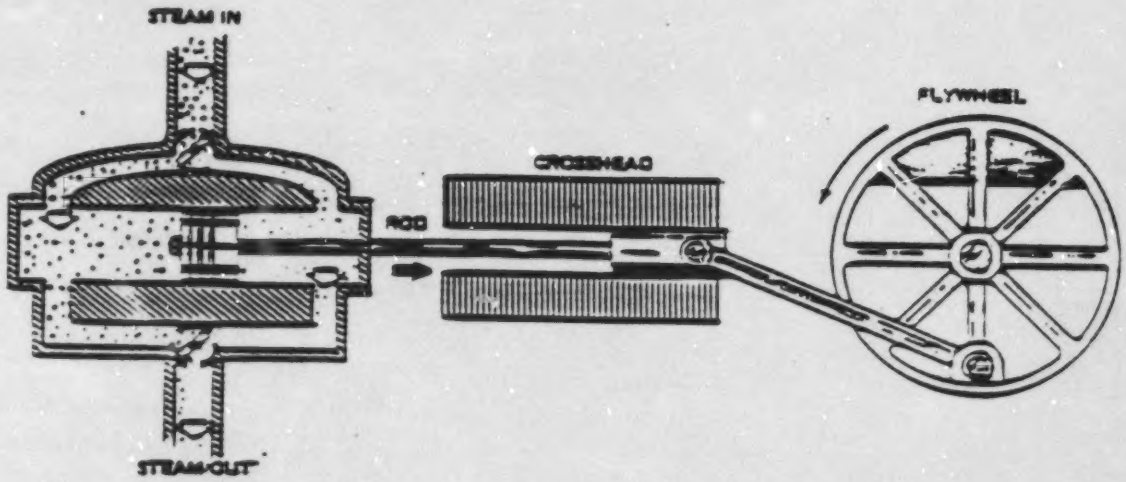

Fig. 2 Steam engine converts reciprocating motion of the piston to circular (rotary) motion of the flywheel.

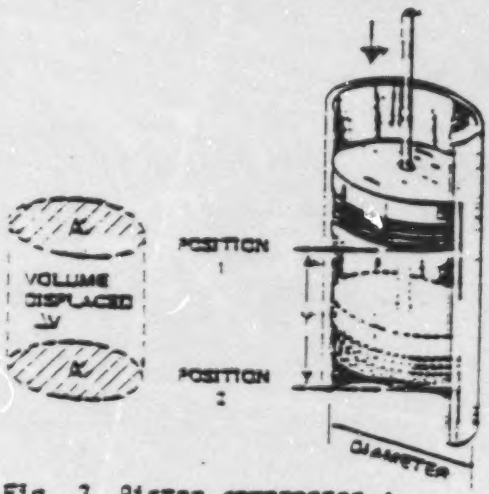

Fig. 3 Piston compresses a gas, changing its volume in the cylinder.

REVIEW:

CALCULATING A CHANGE IN GAS VOLUME

Consider a certain volume of air trapped in the cylinder shown in Figure 3. The piston moves from position 1 to position 2, compressing the air. As the piston is lowered, the volume of the air decreases. The drawing on the side shows the decrease in the volume of the air that is compressed. This decrease in volume is equal to the volume of air displaced by the piston. The exact volume of air displaced can be determined by calculating the volume of a cylinder of height Y and base area A. Base area A is equal to the area of a circle of diameter D. The area of a circle of diameter D is given by $0.7854\ D^2$.

Therefore, the change in gas volume or volume displaced as the piston moves down a distance Y is as follows:

$$(\Delta V) = \left(\begin{array}{c}\text{CROSS-SECTIONAL}\\ \text{AREA OF CYLINDER}\end{array}\right) \times \left(\begin{array}{c}\text{DISTANCE}\\ \text{PISTON}\\ \text{MOVES}\end{array}\right)$$

$$(\Delta V) = (0.7854\ D^2) \times (Y)$$

$$(\Delta V) = 0.7854\ D^2 Y \qquad \text{Equation 1}$$

Knowing values for D and Y, one can find the change in air volume by substituting these values in Equation 1. Example A shows how to do this.

EXAMPLE A: CALCULATING VOLUME OF AIR DISPLACED	
Given:	A piston such as the one shown in Figure 3 moves a distance of 2.0 inches in a cylinder where the inside diameter is 4.0 inches.
Find:	ΔV—the volume of air displaced by the piston (or change in volume of the compressed air).
Solution:	Use Equation 1.
	$\Delta V = 0.7854\ D^2 Y$ where: $D = 4.0$ inches, $Y = 2.0$ inches
	Substitute $D = 4.0$ inches and $Y = 2.0$ inches in the equation, as follows:
	$\Delta V = 0.7854\ (4\ in)^2\ (2\ in)$
	$\Delta V = 0.7854\ (16\ in^2)(2\ in)$ (Use a calculator.)
	$\Delta V = 25.13\ in^3$ $(in^2 \times in = in^3)$
	The piston displaces 25.13 cubic inches of air. The decrease in volume of the trapped air must be equal, also, to 25.13 cubic inches.

SELF-HELP EVALUATION #3

WORK IN FLUID SYSTEMS

COMPLETE THE STATEMENTS BELOW:

1. Name two advantages for pneumatics _____ and _____.

2. Boyles Law states that volume varies _____ as its absolute pressure.

3. Rising temperature causes gases to _____.

4. Pneumatic and electrical systems use similar expressions for doing work.

   Pneumatic work formula _____.
   Electrical work formula _____.

5. Open fluid systems do not make provision for _____.

6. A sump pump lifts 2 cubic meters of water through a pressure difference of 200,000 N/M (squared). The work done by the pump is _____.

INTERMEDIATE OBJECTIVE #3

Describe the rate of fluid flow in the fluid system.

LEARNING STEPS (Activities)

1. Read inforamtion sheet cited in Resource #3 to study an overview of rate.
2. Complete the self-help evaluation cited in Resource #2 to assure your mastery of thsi subject.
3. Perform the activities cited in Resource #3 to evaluate your math skills.
4. Proceed to the next Intermediate Objective.

RESOURCES

1. Information Sheet #5 pages 46 - 56 entitled "Rate in Fluid Systems".
2. Self-help evaluation #2, page 57 entitled "Rates."
3. Activity Sheet #6 pages 59 - 67 entitled "Math Skills II".
4. The next Intermediate Objective begins on page 68.

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DISCUSSION

THE UNIT AND SUBUNITS

Unit 3, "Rate," includes a unit overview (which you are now reading) and four subunits. The subunits are:

- Rate in Mechanical Systems—speed, velocity and acceleration
- Rate in Fluid Systems—volume flow and mass flow
- Rate in Electrical Systems—electrical charge flow or current
- Rate in Thermal Systems—heat flow per elapsed time

You will learn about rate by reading this text, watching video programs, listening to your instructor, participating in class discussions, watching and/or performing demonstrations, and completing eight laboratory exercises.

WHAT IS RATE?

Rate is the relationship between a displacementlike quantity and an elapsed time. Rate always involves how slow or how fast something changes—or how slow or how fast something happens. For example, the rate at which you read the pages in this unit can be determined by dividing the number of pages (displacementlike quantity) by the time (elapsed time) it takes you to read them. If you read seven pages in seven minutes, your reading rate is one page per minute.

Rate is computed by dividing the displacementlike quantity by the elapsed time that it takes for the displacement to occur.

$$\text{RATE} = \frac{\text{DISPLACEMENTLIKE QUANTITY}}{\text{ELAPSED TIME}}$$

Within the four energy systems, the displacement quantities are very different. In mechanical systems, the displacementlike quantity is a distance (mile or meter) or an angle (radians or revolutions). In fluid systems, the displacementlike quantity is a volume (cubic feet) or a mass (kilogram). In electrical systems, the displacementlike quantity is a charge (coulomb). And in the thermal system, it's an amount of heat energy (calories or British thermal units). Although the displacementlike quantities are different, all clearly meet the requirements of the definition for rate.

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In this unit, rate will be discussed in all four systems. For example, both the speed of an automobile in miles per hour—or the rotational speed of an electric drill in revolutions per minute—are examples of mechanical rates. Fluid rates include the measurement of the pulse rate in beats per minute and the output of an oil well in barrels per day. Likewise, the output of an air compressor, measured in cubic feet per minute (or m^3/min), is also a fluid rate. Electrical rates occur in the output of a radar signal in electrical pulses per second—or the tuning of an FM radio in cycles per second (or hertz). Thermal rates are involved in the heating process of a furnace and during the cooling process done by an air-conditioner. Thermal rates are measured in calories per second or British thermal units per hour. (See Figure 3-1.)

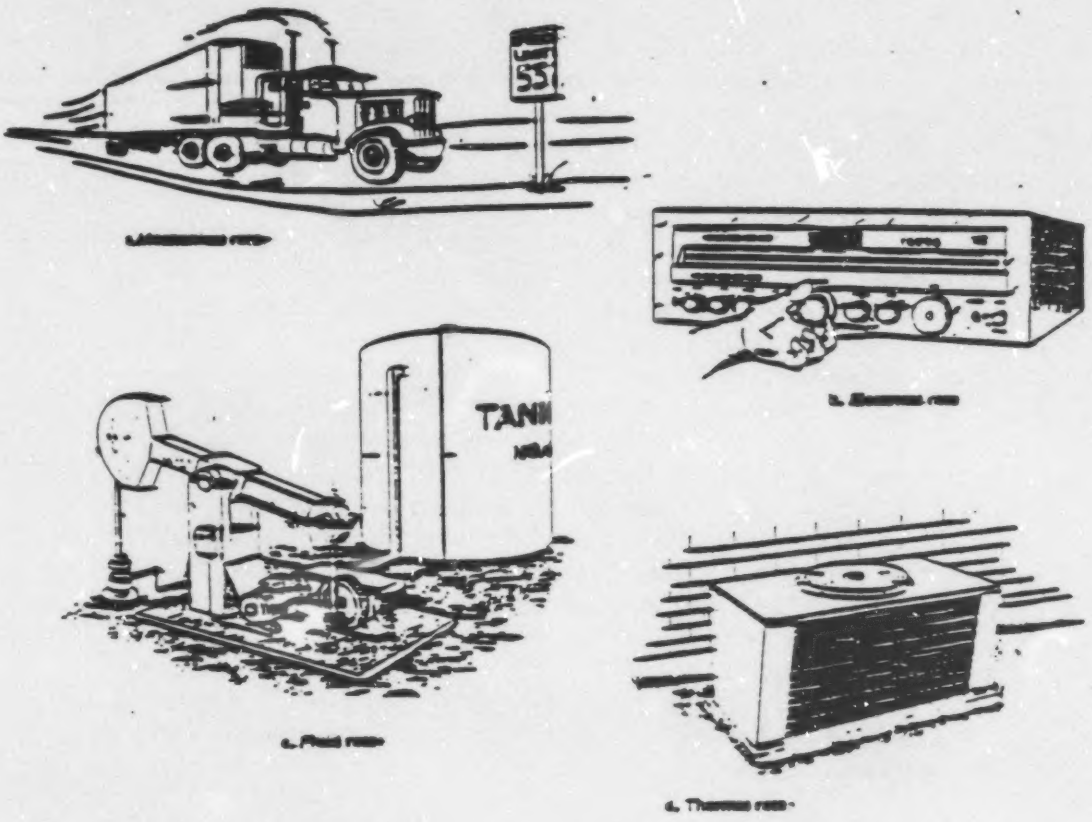

Fig. 3-1 Rate in the four systems.

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A knowledge of rate is important to technicians because rate is an integral part of the industrial realm. In fact, after reading Unit 3, you'll begin to understand that a technician could not operate, maintain, troubleshoot, repair, build or adapt equipment without an understanding of how rate operates in the four energy systems. That's why rate is a unifying concept in the Principles of Technology.

RATE IN THE FOUR ENERGY SYSTEMS

HOW IS RATE USED?

In Unit 1, "Force," you learned that forces can cause an object to start moving, stop moving, speed up, slow down and/or change direction. Forces can also change an object's shape. Since "time marches on" while any of these actions occur, we can describe events in terms of how fast or slow they happen—by measuring rate.

Rate is a general term. We define it by using time as one of the factors. Rates usually measure how fast or how often.

Rates can vary. For example, the speed of light is 300 million meters per sec (186,000 mi/sec). The feed rate on a drill press is about 4 inches per minute (10.16 cm/min). There are big differences in these rates. But both are rates that can be useful information for a technician. More familiar rates may be the speed of the bus that takes you to school or the rate at which a sprinkler applies water to your lawn. Perhaps you have observed a street repair crew resurfacing a street. The machine that does this work can spread asphalt pavement 10 feet wide and four inches deep (3.05 m x 10.16 cm) at a rate of 300 feet per hour (91.44 m/hr). Machines that do work are often described in terms of "rates of performance." (See Figure 3-2.)

In the business, commercial and industrial world, machines perform critical functions that depend on perfect timing. Mechanical, fluid, electrical and thermal systems—or combinations of these systems—convey, move, cut, lift, weld, bore, thread, saw and paint. Each system involves separate rates that are designed to provide a smooth flow of work. The combined rates result in an overall rate for the activity. This overall rate might end up as the number of newspapers printed per day, dollar sales per month—or a production rate for anything from cardboard containers to Learjets.

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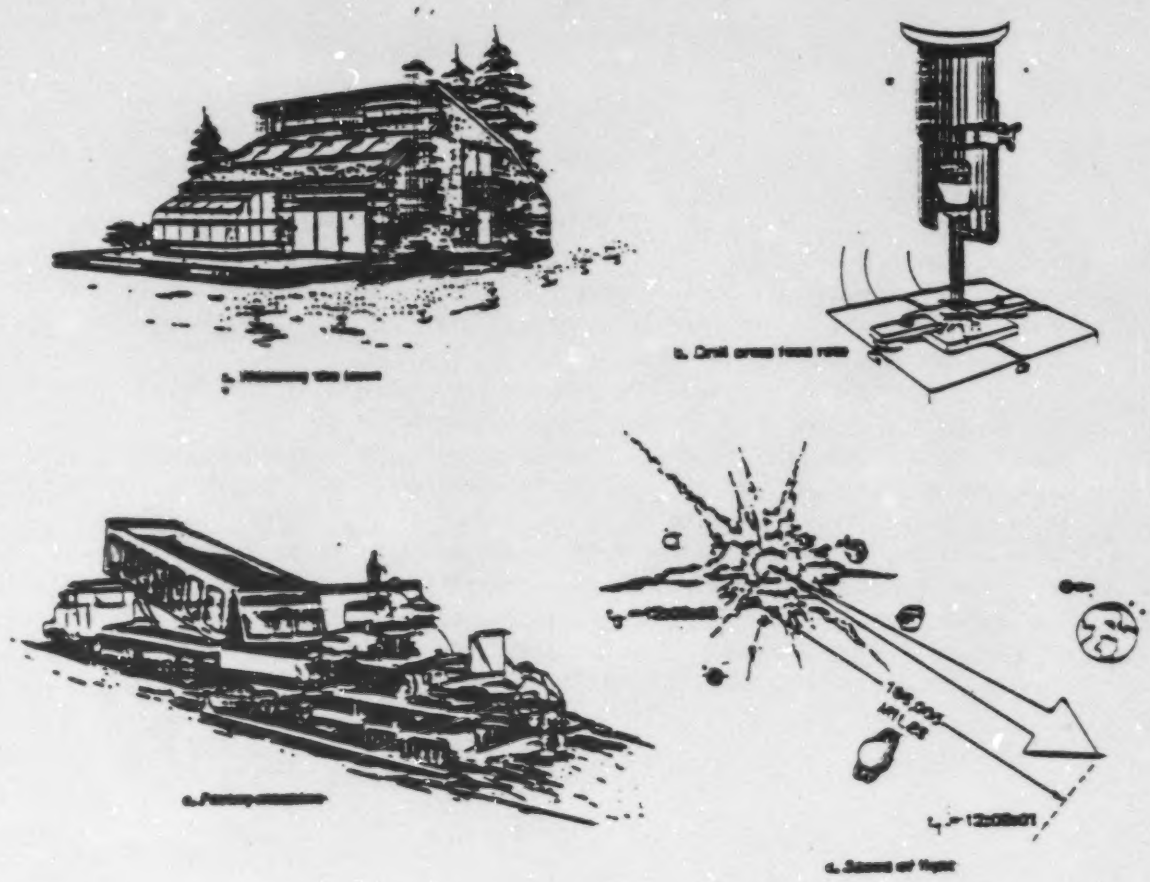

Fig. 3-2 Rates vary depending upon the activity taking place.

TYPES OF RATES AND UNITS OF RATE

Earlier, examples of rates in the four energy systems were given, such as the speed of an automobile, the rate of a heartbeat, the frequency of a radar signal or the output of an air-conditioner. In each case, rate expressed the relationship of a displacement-like quantity to an elapsed time. The physical units used to express rate depend upon the system of units you choose. Both the System International (SI) and English system of units are used to describe rate.

The rate of movement of an automobile involves a distance covered during an elapsed time period. This rate is commonly called "speed." Speed is measured in miles per hour or kilometers per hour. Speed is a rate in a mechanical energy system.

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Likewise, the flow rate from a sprinkler involves a volume displacement during an elapsed time period. Flow is a rate in a fluid energy system. Fluid rate is usually expressed as gallons or liters per minute. We can also express liquid rates in terms of mass flow rates. This is possible because given liquids have a known mass-per-unit volume. Volume is easily converted to mass, as we learned in Unit 1.

In electrical energy systems, the electric current in a motor is simply the charge (or number of electrons) flowing during an elapsed time period. The electrical pulses per second of a radar signal is another example of the application of electrical rate. Thermal energy rate involves the movement of heat energy from regions of high temperature to regions of low temperature in a certain time interval. The rate at which operating machines can be cooled is important to the proper operation of a machine.

In summary, the concept of rate is present in mechanical, fluid, electrical and thermal systems. In each case, rate is an expression of the relationship of a displacement-like quantity to an elapsed time.

DISCUSSION

Fluid systems are common in everyday life. They are common also in commercial and industrial applications. With each fluid system that is operating, there is usually an important fluid rate that has to be controlled or measured. For example, the fan in a heating and air-conditioning system is designed to take stale air from a room, then condition, filter and return the air to the room either as warm air or cool air, depending on the season. The amount of air moved is a rate measured in either cubic meters per minute (m^3/min), or cubic feet per minute (ft^3/min)—or cubic feet per hour (ft^3/hr) in large systems. Fluid rates control how fast a shower or faucet runs; how comfortable a home, office or plant is maintained; and the ease of operation of a car. Many industrial or manufacturing machines also depend on fluid rates.

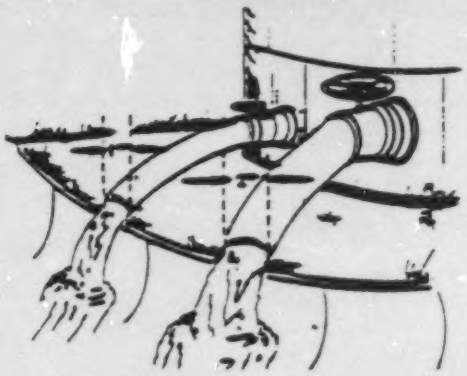


Fig. 3-8 Effect of pipe diameter on volume flow rate.

At first glance, it's tempting to say that rate in fluid systems can be described as a measure of fluid speed. However, fluid rate is involved with volume of flow. Examination shows that if fluid speed in two pipes of different size is the same, less volume of fluid will flow through a small pipe than through a large pipe during the same time. (See Figure 3-8.) This means we must take volume or capacity of fluid into consideration when describing flow rate. Simply stating fluid velocity does not adequately describe flow rate.

VOLUME FLOW RATE

A common rate in fluid flow is called "volume flow rate." This rate is found by dividing a measured volume of fluid moved by the time required for this volume of fluid to flow from a pipe. The fluid moved is often referred to as the displaced fluid. Using a word equation, volume flow rate can be expressed as:

$$\text{VOLUME FLOW RATE} = \frac{\text{VOLUME OF FLUID DISPLACED}}{\text{ELAPSED TIME}}$$

Using symbols, volume flow rate can be written as;

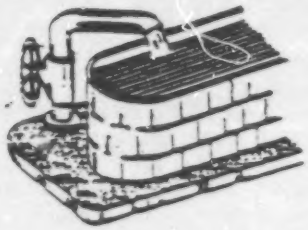
$$Q_v = \frac{V}{t}$$

where: Q_v = volume flow rate
V = volume of fluid moved
t = time of movement

Volume flow rate has many units. Any volume unit divided by a time unit meets the definition. Common volume flow rates include m^3/sec, ft^3/sec, gal/min, liters/sec, etc. Example 3-F illustrates how volume flow rate is determined.

EXAMPLE 3-F: VOLUME FLOW RATE

Given: A tank holds 10,000 gallons; four hours (240 min) are needed to fill the tank at a steady rate.



Find: Volume flow rate of water through the pipe.

Solution: $Q_v = \frac{V}{t}$

$$= \frac{10{,}000 \text{ gal}}{(4 \text{ hr}) \cdot (\frac{60 \text{ min}}{1 \text{ hr}})}$$ (Cancel hr units.)

$$= \frac{10{,}000 \text{ gal}}{240 \text{ min}}$$

Q_v = 83 gal/min; the steady volume flow rate required to fill the tank is 83 gallons each minute.

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MASS FLOW RATE

When the fluid is gas (and sometimes liquid), it's often desirable to consider mass flow rate rather than volume flow rate. Mass flow rate is defined as the fluid mass moving past a given point or position in a given amount of time. Stated in equation form, this rate is written in the following manner:

$$\text{MASS FLOW RATE} = \frac{\text{MASS OF FLUID DISPLACED}}{\text{ELAPSED TIME}}$$

or, written simply,

$$Q_m = \frac{m}{t}$$

where: Q_m = mass flow rate
m = mass of fluid moved
t = time of movement

Example 3-6 demonstrates how mass flow rate can be determined.

EXAMPLE 3-6: MASS FLOW RATE

Given: 180 kg of ammonia gas flowing through the cooling coils of a refrigerated truck in 6 minutes.

Find: Mass flow rate of the gas.

Solution: $Q_m = \frac{m}{t}$

$$Q_m = \frac{180 \text{ kg}}{6 \text{ min}}$$

$Q_m = 30$ kg/min

The ammonia gas is flowing at a rate of 30 kg/min; or, since one kilogram equals 1000 grams, at the rate of 30,000 grams/minute.

MEASURING FLUID RATES

As we have seen, the commonly-used rates for fluid are volume flow rate (Q_v) and mass flow rate (Q_m). Methods for measuring and controlling these two rates vary, depending on the situation. Instruments for reading or determining these rates include direct indicators such as flowmeters (which operate on displacement or movement of the fluid) and indirect indicators for pressure and velocity (which allow flow rate calculations to be made with great accuracy).

CONTROLLING RATES OF FLUID SYSTEMS IN WORKPLACE APPLICATIONS

Workplace applications where fluid system rates are measured include bottling plants for any number of products, from soft drinks to dishwashing liquid. (See Figure 3-9.) In these applications, a pump moves the fluid from a mixing tank to a bottling machine. The rate of flow is set so that the bottles are filled as the conveyor belt moves them into position.

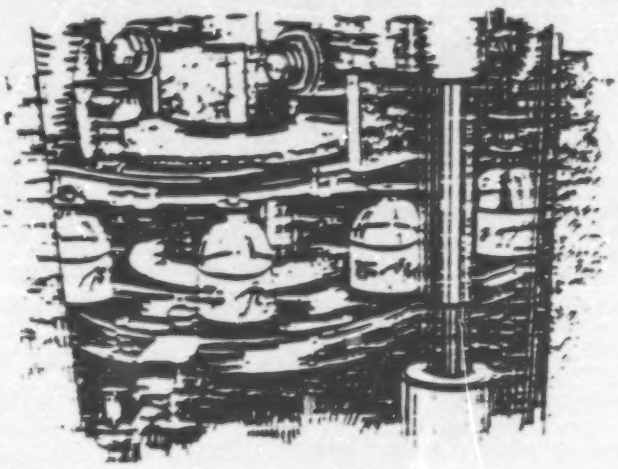

Fig. 3-9 Production rate.

The city water purification plant treats water before introducing it into the supply system. Aeration nozzle ratings in gal/min, or pump capacity in liters/sec, determines the aeration treatment time for the water. This rate is linked directly to the volume flow rate, as well as to the ability of the water system to serve the community.

If the volume flow rate is high, the system must have large pipes that make water available where needed without having to move it rapidly over long distances. Using smaller pipes and higher flow speeds might also meet the demand. But the work required to move the same amount of water through smaller pipes would be higher and, thus, less efficient. (See Figure 3-10.)

Fig. 3-10 A city water treatment system where rate is important.

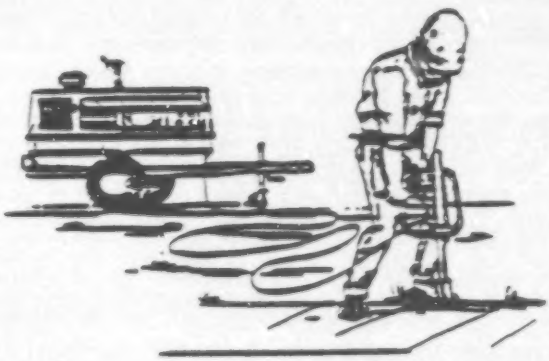

Fig. 3-11 Control of flow rate from air compressor to jackhammer is important.

In the case of gases (especially air, which is in common use), it's necessary to locate the storage tank as close to the point of use as possible. Since air is compressible and is greatly influenced by temperature, traveling long distances through lines at high speeds causes high frictional losses. Locating the compressor and storage tank closer to the point of use makes it easier to maintain the volume flow rates of the system. (See Figure 3-11.)

Firefighters and persons who operate earthmoving equipment are dependent on hydraulic systems to help them perform their heavy work tasks. In earthmoving equipment, the rate of flow of fluids into or out of the equipment's hydraulic cylinders determines how many cubic feet (or cubic yards) of earth or rock can be moved per hour by the machine. In firefighting, both the pumping capacity and nozzle rating of the fire truck and equipment determine how many gallons of water per minute can be placed on a fire. Pumping capacity of fire trucks also determines how high the stream of water can be raised above street level. For tall buildings, this may be many stories high. Having the proper amount of water pressure is crucial to the task of fire fighting. (See Figure 3-12.)

Fluid systems with various flow rate controls are used in plants, commercial and industrial locations to move materials, operate conveyors, and lift and lower elevators. Rate of flow of fluids is an important concept that technicians must master to get a thorough understanding of how fluid systems work.

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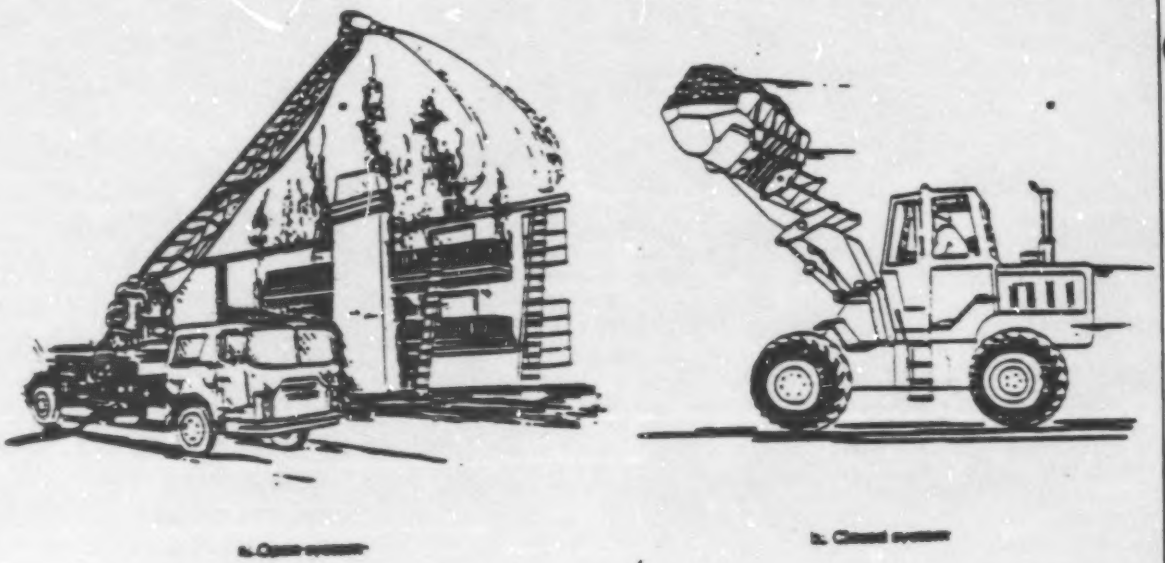

Fig. 3-12 Open and closed systems.

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STUDENT EXERCISES

The following exercises review the main ideas and definitions presented in this subunit, "Rate in Fluid Systems." Complete each question as indicated.

1. The rate associated with a fluid system is _____.
   (Circle the correct answer.)
   a. volume flow rate
   b. fluid speed or velocity
   c. mass flow rate
   d. Both a and c.

The rates associated with the units below may be classified as volume flow rates or mass flow rates. Examine each. Write in the blank provided for each item a "Q_v" for volume flow rate or a "Q_m" for mass flow rate.

2. ___ m^3/sec
3. ___ gram/min
4. ___ liters/sec
5. ___ gal/min
6. ___ kg/min
7. ___ oz/sec

8. In a hydraulic cylinder, _____ (fluid volume, fluid flow rate) determines how fast the piston moves. (Place the correct words in the blank space.)

9. If a leak in a faucet causes a water loss of 120 gallons in two days, what is the volume flow rate per hour (24 hours = 1 day)? (Circle the correct answer and show your work.)

   a. 6.0 gal/hr (Show work here.)
   b. 60 gal/hr
   c. 2.5 gal/hr
   d. 25 gal/hr

10. A car air-conditioner pumps 5 kg of Freon 12 gas through the system in 3 minutes. Find the mass flow rate of the Freon. (Circle the correct answer and show your work.)

   a. 1.7 kg/min (Show work here.)
   b. 12 kg/min
   c. 15 kg/min
   d. None of the above.

11. Where gases are compressed (especially air, which is in common use), storage tanks should be located as close to the point of use as possible because _____. (Complete the explanation in terms of volume flow rate.)

12. The size of pipes delivering fluids over long distances has a direct bearing on making the fluid available where needed. This primarily has to do with _____. (Circle the correct answer.)

   a. volume flow rate control
   b. fluid speed control
   c. Neither a nor b.
   d. Both a and b.

ACTIVITY SHEET #5
MATH SKILLS II

ACTIVITY 1: WRITING DECIMAL NUMBERS IN POWER-OF-10 FORM

DISCUSSION

In Unit 2, "Work," you learned that one coulomb of charge represents 6,250,000,000,000,000,000 electrons. The amount of charge carried by a single electron is 0.00000000000000000001602 coulombs. Very large or very small numbers that require much space and effort to write in decimal notation (as above) are plentiful in technical work. To make large numbers more compact, they are written in a form of notation known as "power-of-10" or "exponential" notation. This method allows the representation of one coulomb of charge to be reduced from 19 numbers to 6.25×10^{18} electrons. The charge carried by an electron goes from 22 numbers to 1.602×10^{-19} coulombs.

To find how this is done, consider the following table.

TABLE I: DECIMAL NUMBER AND POWER-OF-10 EQUIVALENTS

Decimal Number	Power-of-10	Explanation
1,000,000	1×10^6 or 10^6	10 x 10 x 10 x 10 x 10 x 10
100,000	1×10^5 or 10^5	10 x 10 x 10 x 10 x 10
10,000	1×10^4 or 10^4	10 x 10 x 10 x 10
1,000	1×10^3 or 10^3	10 x 10 x 10
100	1×10^2 or 10^2	10 x 10
10	1×10^1 or 10^1	(Usually written without exponent)
1	1×10^0 or 10^0	By definition, any number to zero power equals 1.
0.1	1×10^{-1} or 10^{-1}	$\frac{1}{10}$
0.01	1×10^{-2} or 10^{-2}	$\frac{1}{10 \times 10}$
0.001	1×10^{-3} or 10^{-3}	$\frac{1}{10 \times 10 \times 10}$
0.0001	1×10^{-4} or 10^{-4}	$\frac{1}{10 \times 10 \times 10 \times 10}$
0.00001	1×10^{-5} or 10^{-5}	$\frac{1}{10 \times 10 \times 10 \times 10 \times 10}$
0.000001	1×10^{-6} or 10^{-6}	$\frac{1}{10 \times 10 \times 10 \times 10 \times 10 \times 10}$

Every decimal number can be expressed in power-of-10 notation. The number must be factored into two separate parts, just as 80 can be separated into a product of the factors, 8.0 and 10. In other words, 80 = 8.0 x 10. The first leading factor contains the significant digits of the number, which indicate the accuracy of the number. The second factor, (after the multiplication sign, represented by an "x") is a 10 with an exponent. The exponent is the power-of-10, or how many times 10 is multiplied by itself.

Study Table 2 using Table 1 to verify the answers.

TABLE 2: CONVERSION OF DECIMAL NUMBERS TO POWER-OF-10 (COLUMN B) AND SCIENTIFIC NOTATION (COLUMN C)

Column A	Column B	Column C
375,000	= 375×10^3	= 3.75×10^5
81,000	= 81×10^3	= 8.1×10^4
623,000,000	= 623×10^6	= 6.23×10^8
10	= 100×10^{-1}	= 1.0×10^1
0.0715	= 715×10^{-4}	= 7.15×10^{-2}
0.000000133	= 133×10^{-9}	= 1.33×10^{-7}

PRACTICE EXERCISE FOR ACTIVITY 1

Problem: Convert the decimal numbers in Column A to "power-of-10" equivalents in Column B. (Leave Column C blank for now.)

Column A	Column B	Column C
125,000	_____	_____
32,100	_____	_____
1,521	_____	_____
1,921,000	_____	_____
0.0000192	_____	_____
0.11050	_____	_____
0.567	_____	_____
22	_____	_____

All the following power-of-10 notations express the same number--81,000.

81,000 = 8.1×10^4
= 81×10^3
= 810×10^2
= 8100×10^1
= 0.81×10^5

ACTIVITY 2: WRITING POWER-OF-10 NUMBERS IN DECIMAL FORM

DISCUSSION

Since power-of-10 numbers express where to place the decimal (to the right or left) when rewriting to decimal form, the decimal process is just the reverse of Activity 1.

From Table 1, 10^{4} means that the decimal place is placed four places to the right of 1. So, $1 \times 10^{4} = 10000. = 10{,}000$. If the number is 10^{-4}, then the decimal is placed four places to the left of 1. So, $1 \times 10^{-4} = (0.0001)$.

PRACTICE EXERCISE FOR ACTIVITY 2

Problem: Convert the power-of-10 numbers in Column A to decimal numbers. Place the answers in Column B. (Leave Column C blank for now.)

Column A	Column B	Column C
328×10^{3}		
41.98×10^{4}		
2.12×10^{-4}		
6.1×10^{5}		
3.06×10^{2}		
1.2×10^{-1}		
0.81×10^{5}		

Remember that power-of-10 numbers can be written in more than one way.

ACTIVITY 3: WRITING DECIMAL NUMBERS AND POWER-OF-10 NUMBERS IN SCIENTIFIC NOTATION

DISCUSSION

When converting decimal numbers to power-of-10 numbers, or vice versa, do <u>not</u> round off or drop significant digits. The conversion used should not affect accuracy. While not a fixed rule, the first factor is represented as a number between 1 and 10. This type of expression is a special exponential notation known as scientific notation. Scientific notation is simply a number written as a number between 1 and 10, multiplied by the number 10 that is raised to some power. See Figure 1.

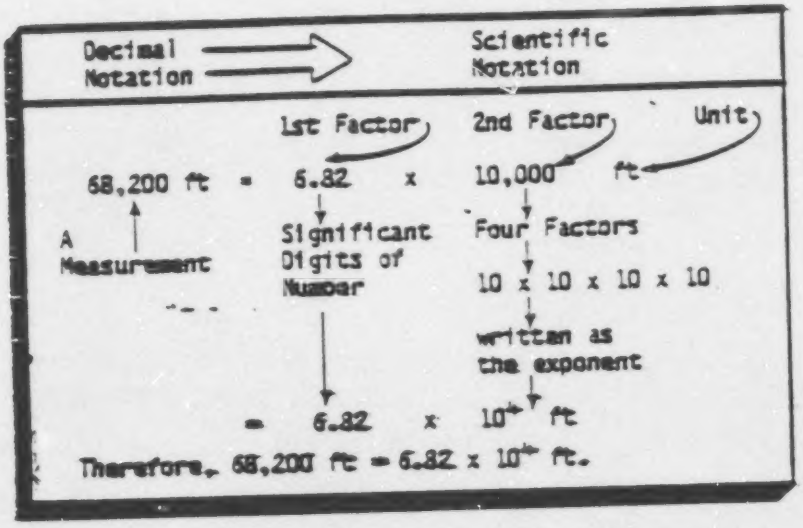

Fig. 1. Expressing a number in scientific notation.

The following numbers in Column C from Table 2 are written in scientific notation as shown below:

3.75×10^{5}	1.0×10^{1}
8.1×10^{4}	7.15×10^{-2}
6.23×10^{8}	1.33×10^{-7}

PRACTICE EXERCISES FOR ACTIVITY 3

Problem 1: Convert the decimal numbers in Exercise 1, Column A, to scientific notation. Place answers in Column C of Exercise 1.

Problem 2: Convert the power-of-10 numbers in Exercise 2, Column A, to scientific notation. Place answers in Column C, Exercise 2.

In a future Math Skills Lab, you'll learn to add, subtract, multiply and divide using power-of-10 numbers. You will also learn how to use a calculator to perform these operations.

ACTIVITY 4. CONDUCTING MATHEMATICAL OPERATIONS WITH NUMBERS EXPRESSED IN POWER-OF-10 FORM

DISCUSSION

In a previous lab exercise, you were required to state decimal numbers in exponential, or power-of-10, form. The exponent of 10 determined placement of the decimal when converting back to decimal numbers.

This exercise will explain how to conduct math operations on numbers with power-of-10 form. Table 1 from your previous lab can serve as a guide to check your work.

The following rules must be observed to obtain correct answers when adding or subtracting power-of-10 numbers.

Rule 1: Any number to the zero power (exponent) is equal to 1.

Examples: $10^0 = 1$; $2^0 = 1$; $5^0 = 1$.

Rule 2: Any number to the first power is equal to that number.

Examples: $10^1 = 10$; $2^1 = 2$; $5^1 = 5$.

Rule 3: Before numbers are added or subtracted, the exponents of 10 must be the same. The first factor need not be between 1 and 10.

Example 1: Add 2.610×10^3 to 6.2000×10^4

$2.610 \times 10^3 = 2.610 \times 10^3$ (left as is)

$6.2000 \times 10^4 = 62.000 \times 10^3$ (changed to a power-of-10^3)

Now add:

$$\begin{array}{r} 2.610 \times 10^3 \\ (+)62.000 \times 10^3 \\ \hline 64.61 \times 10^3 \end{array}$$

or 6.461×10^4

Example 2: Subtract 7.81×10^{-7} from 3.930×10^{-6}

$3.930 \times 10^{-6} = 3.930 \times 10^{-6}$ (left as is)

$7.81 \times 10^{-7} = 0.781 \times 10^{-6}$ (changed to a power-of-10^{-6})

Now subtract:

$$\begin{array}{r} 3.930 \times 10^{-6} \\ (-)\ 0.781 \times 10^{-6} \\ \hline 3.149 \times 10^{-6} \end{array}$$

REMEMBER: The number 10 raised to different exponential powers cannot be added or subtracted any more than apples and oranges can.

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PRACTICE EXERCISES FOR ACTIVITY 4

Problem 1: ADD the following numbers in exponential form.

$3.172 \times 10^{4} =$
$+ \underline{6.210 \times 10^{3} =}$

$52.73 \times 10^{3} =$
$+ \underline{21.326 \times 10^{4} =}$

$1.235 \times 10^{-11} =$
$+ \underline{21.6 \times 10^{-13} =}$

SUBTRACT the following numbers in exponential form.

$4.631 \times 10^{-7} =$
$- \underline{6.82 \times 10^{-8} =}$

$18.21 \times 10^{4} =$
$- \underline{122.1 \times 10^{3} =}$

The following rule applies to multiplying power-of-10 numbers.

Rule 4: The first factors (decimal part) of each number are multiplied. But the exponents of 10 are added algebraically. The result is a product of the first factors times (x) a power of 10.

Example 1: $(3.2 \times 10^{4}) \times (1.5 \times 10^{2})$
$= (3.2)(1.5) \times 10^{4+2}$
$= 4.8 \times 10^{6}$

Example 2: $(3.2 \times 10^{-3}) \times (1.5 \times 10^{2})$
$= (3.2)(1.5) \times 10^{-3+2}$
$= 4.8 \times 10^{-1}$

Problem 2: MULTIPLY the following numbers in exponential form.

$(5.5 \times 10^{3})(2 \times 10^{4})$

$= \_\_\_\_\_$

$= \_\_\_\_\_$

$(2.2 \times 10^{-3})(2.5 \times 10^{4})$

$= \_\_\_\_\_$

$= \_\_\_\_\_$

$(9 \times 10^{5})(4 \times 10^{-2})$

$= \_\_\_\_\_$

$= \_\_\_\_\_$

The following rules apply to dividing power-of-10 numbers.

Rule 5: Whenever 10 has a power with a negative sign, such as 10^{-1} or 10^{-2}, it is equal to the number, one, divided by 10 with the same power and a positive sign. For example:

$$10^{-1} = \frac{1}{10^{1}} = \frac{1}{10}$$

$$10^{-2} = \frac{1}{10^{2}} = \frac{1}{10 \times 10} = \frac{1}{100}$$

$$10^{-3} = \frac{1}{10^{3}} = \frac{1}{10 \times 10 \times 10} = \frac{1}{1000}$$

Rule 6: In division, the first factors of each number are divided. But the exponents of 10 are subtracted algebraically. The result is the quotient of the first factors times (x) a power of 10.

Example 1:
$$\frac{8.4 \times 10^{9}}{2.1 \times 10^{4}} = \frac{8.4}{2.1} \times 10^{9-4}$$
$$= 4.0 \times 10^{5}$$

Example 2: $\frac{8.4 \times 10^{7}}{2.1 \times 10^{-3}} = \frac{8.4}{2.1} \times 10^{7-(-3)}$ (NOTE: A "minus times a minus" is equal to a "plus," thus -(-3) is equal to +3.)

$= 4.0 \times 10^{10}$

Problem 3: DIVIDE the following numbers in exponential form.

$\frac{3.6 \times 10^{5}}{1.2 \times 10^{3}} = \_\_\_ \times \_\_\_\_\_$

$\frac{9.6 \times 10^{6}}{8 \times 10^{-4}} = \_\_\_ \times \_\_\_\_\_$

$\frac{10.5 \times 10^{-3}}{5 \times 10^{-1}} = \_\_\_ \times \_\_\_\_\_$

ACTIVITY 2: USING POWERS-OF-10 NUMBERS TO SOLVE PRINCIPLES OF TECHNOLOGY PROBLEMS

DISCUSSION

This activity will combine the skills learned in calculating unknowns when using power-of-10 numbers. These skills are best learned by practice.

Problem 1:

Given: An air-conditioner duct has a pressure difference of 125.5×10^{-4} lb/in^2 when the fan moves 50,000 in^3 of air.

Find: Work done by the fan.

Solution: WORK = PRESSURE DIFFERENCE x VOLUME MOVED.

$W = \Delta P \times V$

$W = (125.5 \times 10^{-4} \frac{lb}{in^2})(50{,}000\ in^3)$

$W = (125.5 \times 10^{-4})(5 \times 10^{4}) \frac{lb}{in^2} \times in^3$

$W = (125.5)(5) \times 10^{-4+4}$ in·lb

$W = 632.5 \times 10^{0} = 632.5$ in·lb.

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Problem 2:

Given: A bullet leaves the barrel of a rifle with a speed of 0.125×10^3 m/sec.

Find: Distance traveled in three seconds.

Solution: SPEED = $\frac{\text{DISTANCE TRAVELED}}{\text{ELAPSED TIME}}$, or $v = \frac{d}{t}$.

$v = \frac{d}{t}$ (To find distance, isolate d by multiplying both sides of equation by t.)

$tv = \frac{td}{t}$ (Cancel t's.)

This leaves $d = vt$.

$d = (0.125 \times 10^3 \frac{m}{sec})(3\ sec)$ (Cancel seconds.)

$d = (0.125\ m)(3) \times 10^3$

$d = 0.375 \times 10^3$ m

$d = 375$ m.

PRACTICE EXERCISE FOR ACTIVITY 5

Problem: Given: Several forces were recorded by sensors in a test on an aircraft wing at one point. These forces, all acting in the same direction, were as follows:

$f_1 = +1.22 \times 10^2$ oz

$f_2 = +3.1 \times 10^3$ oz

$f_3 = +1.08 \times 10^5$ oz

Find: The total force (F) at the point mentioned.

Solution: $F = f_1 + f_2 + f_3$

$F =$ _____.

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INTERMEDIATE OBJECTIVE #6

Describe the similarities of related technology circuits and components.

LEARNING STEPS (Activities)

1. Read Information Sheet cited in Resource #1 to recognize technology similarities.

2. Complete the written criteria evaluation cited in Resource #2 to prove mastery of this Intermediate Objective.

3. Upon satisfactory completion step #2 above, proceed to the next learning guide.

RESOURCES

1. Information Sheet #6 page 69 - 75 entitled "Unified Technology Concepts".

2. See your instructor for the criteria evaluation for this Intermediate Objective.

3. See your instructor for learning guide 212.

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INFORMATION SHEET #6

UNIFIED TECHNOLOGY CONCEPTS

OBJECTIVE: To recognize the similarity of related technology circuits and components

Throughout the decades there has been a consistant segregation of technologies. FLUID POWER has been presented as both Pneumatic and Hydraulic and never being related to ELECTRICITY! As electricity is not related to fluid power.

AMPTRONICS, a divtsion of TII ROBOTIC SYSTEMS INC. would like to present a new concept to the student, a UNIFIED TECHNOLOGY course that will enable a student to identify circuits both in electricity, pneumatics and hydraulics, with the main emphasis on pneumatics.

A "UNIFIED TECHNOLOGY" circuit can best be explained as one circuit redrawn using electrical, pneumatic and hydraulic symbols. All circuits have a POWER SOURCE, A PATH OF TRAVEL and a LOAD.

Study the circuits on the following page and note that they are all identical except for the component symbols! A quick reference chart for basic electrical symbols can be found at the end of this activity inorder to aid you in recognizing the various electrical symbols. Refer to the GRAFIC SYMBOLS section of your other manuals for pneumatic and hydraulic symbols.

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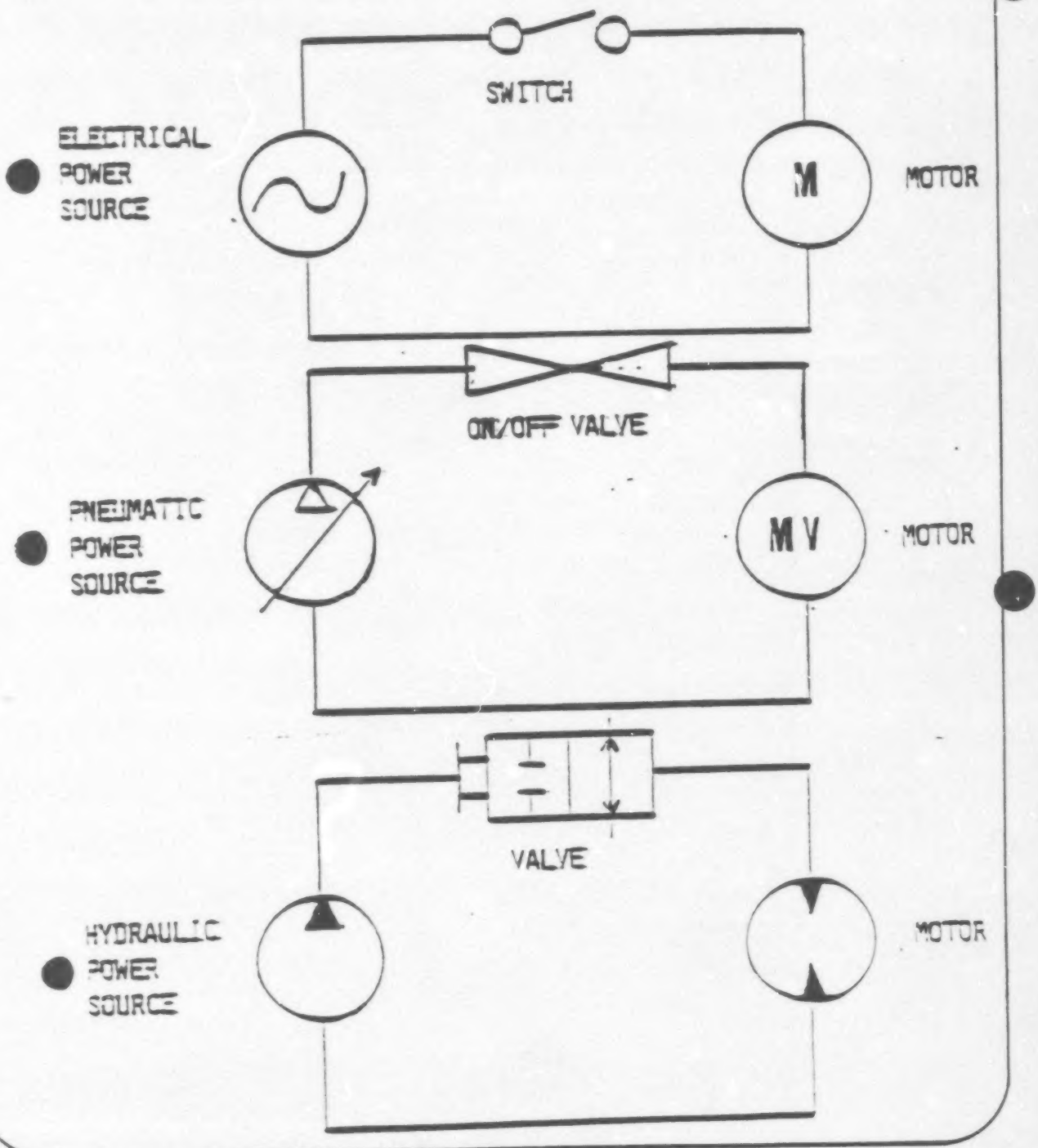
UNIFIED TECHNOLOGY CONCEPTS



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INFORMATION SHEET

Each source of power may take many forms, such as AC & DC electrical power, compressed air or a hydraulic system. Switches, valves and loading devices will also take many different forms, however, all components regardless of the technology, will be dictated by the application needs!

When studying an application problem, the "UNIFIED TECHNOLOGY CONCEPT" can be applied. After all surrounding conditions have been determined, one of the three concepts, (electrical, pneumatic, or hydraulic) can be used.

As you proceed through the following activities, take the time to draw each circuit using the "UNIFIED TECHNOLOGY CONCEPT". As your abilities increase, you will find that each circuit and application may have a more suitable alternative depending upon the surrounding environment of the application.

Using your present Electrical course manual or the QUICK REFERENCE GUIDE supplied in this manual and the "ROBOTIC APPLICATIONS FOR PNEUMATICS & HYDRAULICS", layout and draw the following circuit for all three technologies. Use any switching or load devices that you may choose.

Additional work sheets have been provided so you may try your abilities in the "UNIFIED TECHNOLOGY CONCEPT" of some of the activities in this manual.

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INFORMATION SHEET

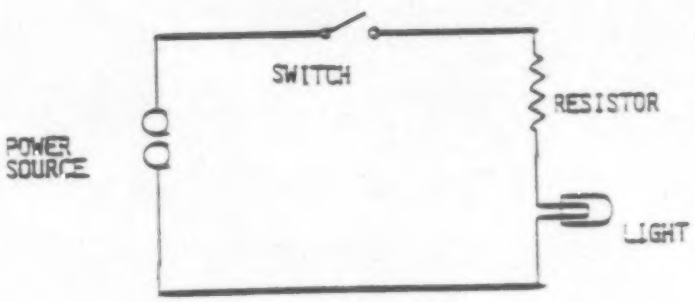
UNIFIED TECHNOLOGY CONCEPTS

WORKSHEET

- PNEUMATIC CIRCUIT

- HYDRAULIC CIRCUIT

- ELECTRICAL CIRCUIT



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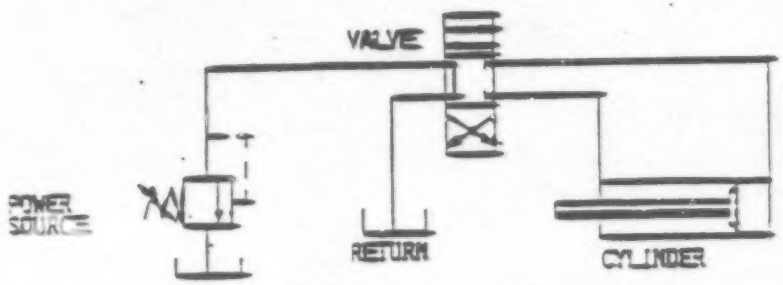
WORKSHEET

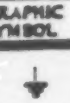
- PNEUMATIC CIRCUIT

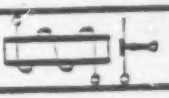
- HYDRAULIC CIRCUIT



- ELECTRICAL CIRCUIT

ELECTRICAL QUICK REFERENCE CHART

COMPONENT DESCRIPTION	GRAPHIC SYMBOL	LETTER SYMBOL
Connection, ground		gnd
Diode, semiconductor		CR
Field Effect (Junction) Transistor, N Channel		Q
P Channel		Q
Fuse		F
Galvanometer		G
Generator		GEN
Lamp		LP
Meter (insert letter indicating function V = voltmeter A = ammeter, etc.)		M
Milliammeter		mA
Millivoltmeter		mV
Motor, ac		MOT
Motor, dc		MOT
Neon Lamp		LP
Ohmmeter		OHM

COMPONENT DESCRIPTION	GRAPHIC SYMBOL	LETTER SYMBOL
Potentiometer		R
Resistor, fixed		R
tapped		R
Relay, normally closed (NC)		K
Thermistor		R
Silicon Controlled Rectifier (SCR)		Q
Solenoid Coil		SC
Speaker		SPKR
Switch, Single-Pole-Single Throw (SPST)		S
Single-Pole-Double-Throw (SPDT)		S
Double-Pole-Single-Throw (DPST)		S
Double-Pole-Double-Throw (DPDT)		S
Pushbutton, normally closed (PBNC)		S
Pushbutton, normally open (PBNO)		S
Rotary		S

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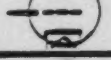
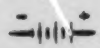
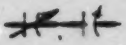
ELECTRICAL QUICK REFERENCE CHART

COMPONENT DESCRIPTION	GRAPHIC SYMBOL	LETTER SYMBOL
Terminal		
Thermistor		RT
Thermocouple		TC
Transformer, Air Core		T
Iron Core		T
Autotransformer		T
Transistor NPN		Q
PNP		Q
Vacuum Tube diode		V
triode		V
pentode		V
Voltmeter		V
Wattmeter		W
Zener diode		CR

COMPONENT DESCRIPTION	GRAPHIC SYMBOL	LETTER SYMBOL
AC generator		GEN
Ammeter		A
Battery		B
Capacitor, fixed		C
electrolytic (fixed)		C
variable		C
Cell		B
Conductor		
cross, no connection		
connection		
Coil, air core		L
Coil, adjustable		L
Coil, fixed tap		L
Coil, iron core (choke)		L
Connection, chassis		

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PROGRAM INDUSTRIAL ELECTRICAL MAINTENANCE

CRITERION EXAM

TASK = 211 DESCRIBE UNIFIED TECHNOLOGY CONCEPTS

DIRECTIONS:

THE PURPOSE OF THIS EXAM IS TO DETERMINE WHETHER OR NOT YOU HAVE UNDERSTOOD THE INFORMATION ON UNIFIED TECHNOLOGY CONCEPTS.

Each of the questions or incomplete statements below is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A,B,C or D) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer 10 out of 10 items correctly, 100 %.

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EVALUATION SHEET

UNIFIED TECHNOLOGY CONCEPTS

1. Charles Law states:

2. When a moving piston does work in a hydraulic cylinder, the pressure exerted by the piston is multiplied by _____.

   A. area of the piston face
   B. fluid volume displaced
   C. weight density of the fluid

3. Pneumatic and electric systems use similar mathematic expressions for doing work. Write the expressions for each below.

   Pneumatic work formula equals _____

   Electric work formula equals _____

4. Open fluid systems do not make provision for _____.

5. The term "mass flow rate" is symbolized using Qm. Complete the expression for Qm:

6. The term "Volume flow rate" refers to _____divided by elapsed time.

7. Write .00000148 in scientific notation. _____

8. Write the expression 1.23 X 10E-4 in decimal notation. _____

9. Add these two fractions: 12/45 plus 6/135 = ? .

10. All circuits have a _____, a _____ and a load.

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LAKE
COUNTY
AREA
VOCATIONAL
CENTER

COMPETENCY-BASED INDIVIDUALIZED VOCATIONAL EDUCATION INSTRUCTION

STUDENT LEARNING GUIDE

Produced By M. H. WHITMER Date 4/85

TASK: IDENTIFY FLUID SYSTEM COMPONENTS

PURPOSE: You must understand fluid system components as they apply to robotics and automated manufacturing. The intermediate objectives under this task presents the fluid system components to help you achieve the needed understanding. The modern electrical maintenance person knows how fluid systems work so that troubles can be identified and repairs effected rapidly.

INDUSTRIAL ELECTRICAL MAINTENANCE

Program	Task	Est.Time	Prereq.
17.1002	212	2 hrs	211

edk

LEARNING CONTRACT (optional)

1. STUDENT DATA

NAME _____ SOCIAL SECURITY NUMBER _____

LENGTH OF CONTRACT (NORMAL TIME IN HOURS) _____

2. TERMINAL PERFORMANCE OBJECTIVE

Given a written evaluation and a performance checklist, you will identify fluid system components on the written evaluation and select the correct components from those supplied with the trainer. You must score 100% on the written test and 100% on the performance checklist for this objective.

2a. INTERMEDIATE OBJECTIVE(s)

1. Identify air and hydraulic components.
2. Identify common electrical sensors.

3. AGREEMENT

I, _____ agree to complete the above stated terminal performance requirement within _____ to _____ I further recognize that the conditions of the contract (performance and time agreement) report my ability to perform the requirements of the occupation and record my progress.

Student's Signature _____

Instructor's Signature (verifies competency) _____

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INTERMEDIATE OBJECTIVE

Identify air and hydraulic components.

LEARNING STEPS (Activities)

1. Read the information sheets cited in Resource #1 to learn the fluid components.
2. Complete the self help exam cited in Resource #2, to assure mastery of the subject.
3. Proceed to the next Intermediate Objective.

RESOURCES

1. Information Sheet #1, starts on page 4 and is entitled "Popular Fluid Components".
2. Self-help Exam #1 begins on page 13 and is entitled "SelfHelp on Fluid and Electrical Components."
3. The next Intermediate Objective begins on page 15.

INFORMATION SHEET #1

"FLUID COMPONENTS"

In most air and hydraulic fluid power circuits, valving is used to control (a), direction of fluid flow, (b), rate of fluid flow, and (c), maximum level of pressure. Control valves for these three functions can be purchased with solenoid actuators. It is then possible to control these functions remotely or to tie the valve action into an overall electrical circuit for atuomatic or semi-automatic action, or remote control.

Directional valves are the ones most often operated by solenoids, although to a limited extent 2-way solenoid controlled valves are used for deceleration control, step level pressure control, pump unloading, and flow control (usually on hydraulics).

Air valves and hydraulic valves both operate in the same way and are electrically controlled in thesame way but overall circuitry for the two fluid mediums is different. For example, most air circuits use 2-position solenoid valves and hydrolic circuits use 3-positions valves. Pump unloading must air circuits use 2-position solenoid valves and hydraulic circuits use 3-positions valves. Pump unloading must be considered when designing for hydraulics but is not a requirement when designing for air. After careful consideration of the best way to present both air and hydraulic circuitry, we have decided to present each topic, such as cylinder reciprocation, cylinder sequencing, safety circuits, ect., and to give examples first of air circuitry then of hydraulic circuitry before proceeding to the next topic.

We are briefly describing some of the electrical components available for control of fluid power for the benefit of those who may have some familiarity with fluid power but not with electrical control. The electrical components described here represent only a small proportion of the large variety available to the designer. Our listings are intentionally limited to the most widely used types; those which are most often used for control of fluid power, and we have tried to select for illustration those components available from several manufacturers rather than those of a proprietary nature available only from one source. Some manufacturers rather than those of a proprietary nature available only from one source. Some manufacturers may offer components which serve the purpose equally well but which have a somewhat different appearance. To completely describe all similar equipemnt would require a large book devoted entirely to this subject.

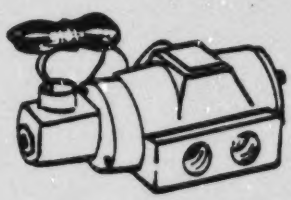
A. FLUID COMPONENTS AVAILABLE—AIR AND HYDRAULIC

1. Directional Control Valves — 4-Way

A directional valve is defined as one which controls the direction of flow of a fluid, either liquid or air, in a fluid power circuit. Flow direction of the fluid determines the direction of travel of a cylinder, forward or reverse, and the direction of rotation, clockwise or counter-clockwise, of a fluid motor. While most circuits require only one directional valve for each output actuator (or group of actuators), there are some circuits for special purposes which may require several in order to obtain the range of control needed.

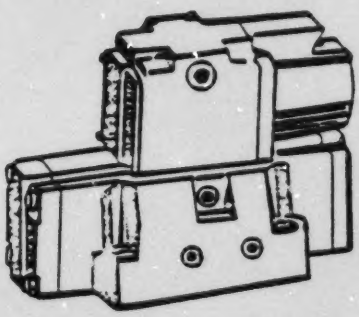
Four-way directional valves are usually considered as standard for operation of a double-acting cylinder. They are built in a wide variety of shapes and sizes, and may vary in appearance from those shown in our illustrations, but the solenoid valves shown are sketched from popular brands in common use.

Electrically controlled directional valves respond to an electrical signal for shifting their spools or poppets, to provide different flow paths through the internal porting to their outlet ports. They are built as 2-way, 3-way, 4-way, and 5-way types. The student is referred to "Industrial Fluid Power — Volume 1"* for further description of these types. In the majority of applications, 4-way valves are used for control of double-acting cylinders and reversible fluid motors.

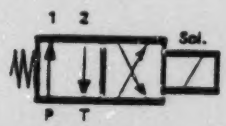


A. Typical Air Valve

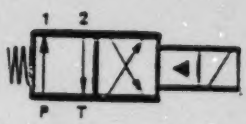
Single Solenoid 4-Way Valves. Figure 1-1. This type is identified by its having only one solenoid coil. When this coil is energized, the valve spool is shifted against spring force to its opposite side position and held in this position as long as the solenoid coil remains energized. The single solenoid valve is said to require a "maintained" electrical signal to keep its spool shifted. There are only two valving positions; no center neutral spool positioning is possible.



B. Typical Hydraulic Valve.



C. *Graphic Symbol for Direct-Acting Single Solenoid 4-Way Valve.*



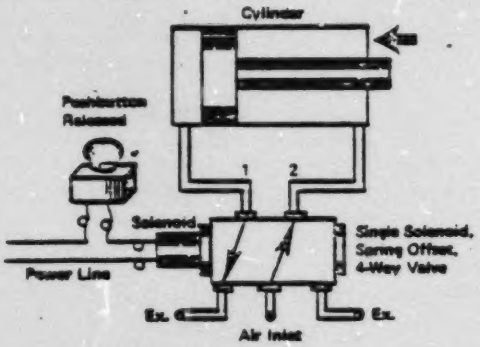
D. *Graphic Symbol for Pilot-Operated Single Solenoid 4-Way Valve.*

(P is pressure port; T is tank return on hydraulic valve, exhaust on air valve; 1 and 2 are cylinder ports).

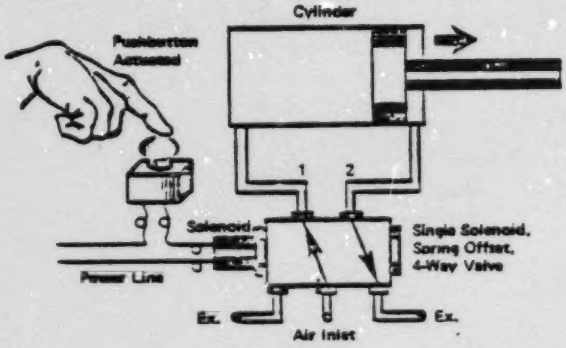
FIGURE 1-1. Single Solenoid 4-Way Valves.

**Textbook available from Womack Educational Publications. See title page for address of publisher.*

Action of a Single Solenoid Valve. Figure 1-2. The basic action of a single solenoid valve in controlling a standard double acting cylinder is shown in the two illustrations below. A pushbutton is wired in series with the valve coil to the 115-volt power line. During the time the button is not actuated, Part A figure, the valve spool is held in its normal side position by an internal spring, and fluid pressure is directed to the rod end of the cylinder, which causes it to retract, and holds it against the rear end cap with full pressure. Note: If fluid lines 1 and 2 to the cylinder were to be reversed, the starting position of the cylinder would be at full extension.



A. Cylinder retracts when normally open electric pushbutton is released.



B. Cylinder extends when normally open electric pushbutton is pressed.

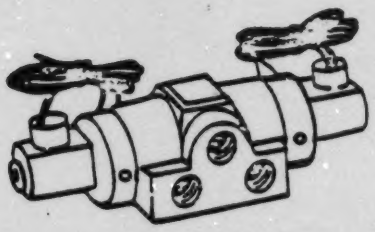
FIGURE 1-2. Pushbutton Control of an Air Cylinder With a 4-Way Single Solenoid Valve.

When the button is pressed, Part B of the figure, the solenoid shifts the valve spool to its opposite side position, and fluid pressure is directed to the blind end of the cylinder causing the piston rod to extend, and eventually holding it against its forward end cap under full pressure. However, if at any point in the piston stroke the button is released, the valve spool will be returned to its normal position and the cylinder will immediately start its retraction stroke even though the forward stroke has not been completed.

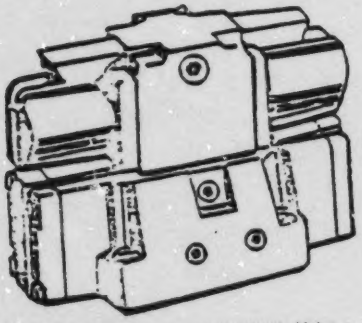
Since there can be no neutral position on a single solenoid valve, there is no electrical means by which the cylinder piston can be stopped in between its extremes of travel.

Double Solenoid 4-Way Valves: Figure 1-3. A double solenoid valve can be identified by its having two solenoid coils, usually on opposite ends of the valve body. However, a visual inspection may not reveal whether the valve is a 2-position model, or a 3-position model with center neutral position. This information can be obtained either by comparing its nameplate model number with the manufacturers catalog, or by physical inspection, removing the spool to look for centering springs.

Valves with no centering springs on the spool are called "2-position, no-spring" models. Those with centering springs as "3-position, spring centered". However, some large valves may have pressure centered spools.



Typical Double Solenoid Air Valve.



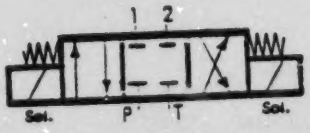
Typical Double Solenoid Hydraulic Valve.

FIGURE 1-3. Examples of Double Solenoid 4-Way Valves.

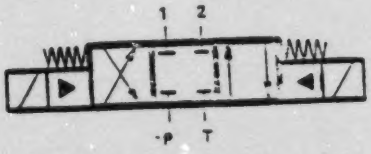
Direct-Acting Double Solenoid Valve.

Pilot-Operated Double Solenoic Valve.

FIGURE 1-4. Graphic Symbols for 2-Position Double Solenoid 4-Way Valves, Air or Hydraulic. (P is pressure port; T is tank return or air exhaust; 1 and 2 are the Two Cylinder Ports).



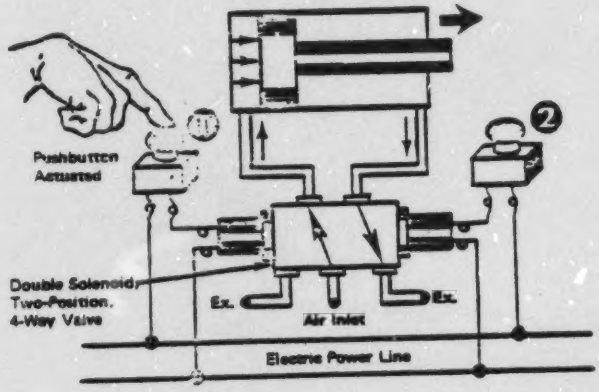
Direct-Acting Spring Centered Double Solenoid Valve.



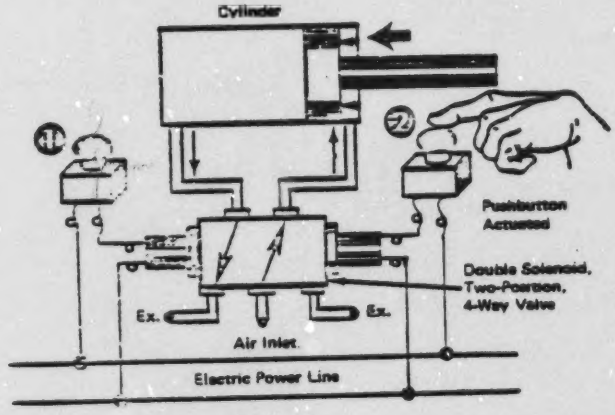
Pilot-Operated Spring Centered Double Solenoid Valve.

FIGURE 1-5. Graphic Symbols for 3-Position, Double Solenoid 4-Way Valves. (Air or Hydraulic)

Action of Double Solenoid Valve. Figure 1-6. The illustrations on this page show the action of a 2-POSITION double solenoid valve in operating a standard cylinder, air or oil. A 2-position valve is said to require a "momentary" electrical signal for its operation. Once the valve spool has been shifted by solenoid action, it will remain in that position, even though the solenoid is de-energized, until the opposite solenoid is energized. Most valves will shift reliably on a signal duration as short as 1/10th second.



A. Cylinder extends when electric pushbutton on the left is pressed.*



B. Cylinder retracts when electric pushbutton on the right is pressed.*

Part A, Figure 1-6. When the left pushbutton, 1, is momentarily pressed, the valve spool is shifted to its opposite position, directing inlet air to the back side of the cylinder piston, causing it to move forward. It will continue to travel until it stalls against the work or against its front end cap.

Part B, Figure 1-6. Pressing the pushbutton on the right shifts the valve spool back to its original position, which directs air flow into the rod end of the cylinder. The piston retracts until reaching stall against its rear end cap.

Reversal can be made to take place at any point in the piston stroke while the piston is traveling. But since the valve has only two working positions, there is no electrical means by which the piston can be stopped at any intermediate point in its travel.

Design Note: All spool-type 4-way valves should preferably be mounted with spool in a horizontal plane to avoid the possibility of self-shift due to excess flow or vibration.

FIGURE 1-6. Pushbutton Control of a Cylinder With 2-Position Double Solenoid Valve.

**Some brands of double solenoid valves may have reverse action: Energizing left solenoid may cause cylinder to retract.*

Action of 3-Position Double Solenoid Valve. Please refer to Figure 1-6. That illustration may also be used to describe the action of a 3-POSITION valve in controlling a standard double-acting cylinder.

Electrical connections are the same whether for a 2-position or a 3-position valve, but the internal action is different on the two types, and the overall electrical control circuit must be designed differently. The 3-position type has a spring centered neutral position of its spool, and this center spool position is used to stop a cylinder at any intermediate point between the two extremes of its piston travel. Because of centering springs on the valve spool it is necessary to hold current on one solenoid or the other to keep the valve spool in one of its side positions for keeping the cylinder in motion. Therefore, a 3-position valve is said to require a "maintained" electrical signal for its operation; anytime both solenoids are de-energized the valve spool will become centered and the cylinder will stop.

Note: Some brands of double solenoid valves will have one coil burn out if both coils are energized at the same time and if this condition is maintained very long or repeated very often. This includes all those valves where the two solenoids are connected to opposite ends of the same spool. When using valves of this type the electrical circuit should be arranged to make it impossible to have current on both solenoids at the same time. Interlocking circuits are shown in Chapter 8.

2. Directional Control Valves – 3-Way, Single Solenoid.

Used principally to control single-acting air cylinders; sometimes, but not often, used to control hydraulic cylinders on very special applications some of which are described in "Volume 2 – Industrial Fluid Power". Sometimes used for vacuum control.

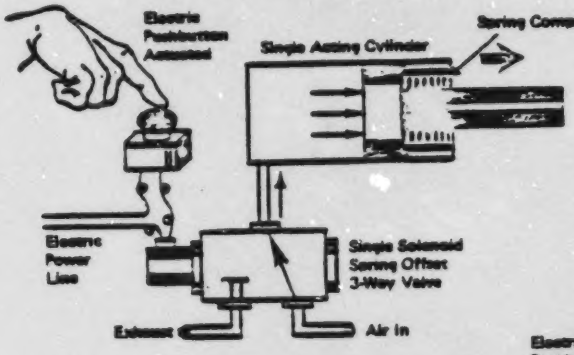
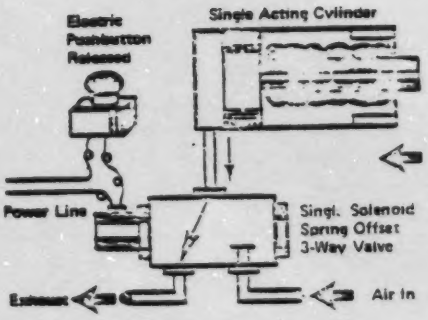


FIGURE 1-7. Action of a 3-Way Valve in Controlling a Single-Acting, Spring Return Cylinder.

Above: When pushbutton is pressed, valve spool shifts, directing fluid pressure behind the cylinder piston, causing it to move forward.

Right: When button is released, valve spool returns to original position, venting cylinder piston to exhaust, allowing internal spring to return cylinder piston to normal position.

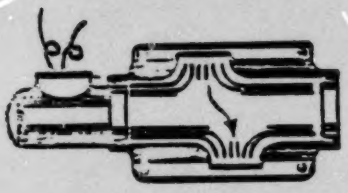


Spool-type 3-way valves are usually similar in appearance and construction to 4-way valves of the same brand, but may be shorter in length. From most manufacturers they are available only in single solenoid models, with either a N.O. (normally open) or N.C. (normally closed) configuration. A few manufacturers may offer them in 2-position and 3-position double solenoid models. However, most applications for 3-way valves do not require anything more elaborate than single solenoid action.

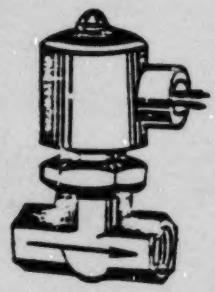
When 3-way action is needed from a spool valve the most often-used arrangement is to use a standard 4-way spool valve and install a plug in the cylinder port which is not used. One advantage is that by choosing the correct cylinder port to use, the 4-way valve may be made into either a N.O. or N.C. 3-way valve. It would be wise to check valve specifications before plugging any port on a 4-way valve. Some brands may have packings unseated or may develop spool bind if ports are permanently plugged.

3. Two-Way Solenoid Valves

Figure 1-8. Two-way solenoid valves are classed as "directional" valves, although their action is only to open and close by solenoid motivation. They are used to start and stop the flow of fluids — air, oil, water, etc. Solenoid operation permits them to be controlled from a remote location, or allows them to be wired into an automatic cycle with other electrically operated equipment. In special circuitry, shown later in this book, they can be used in groups of two, three, or four to obtain valving flexibility not possible with one 3-way or 4-way valve.



A. Spool-Type 2-Way Valve.



B. Poppet-Type 2-Way Valve.

FIGURE 1-8. 2-way, 3-way, and 4-way valves may be constructed to operate either on the poppet or sliding spool principle.

Poppet action and sliding spool action are the two modes of construction most often used for construction of directional valves. An example of the general appearance of each type is given above. Poppet construction is most popular for 2-way valves, and is also used extensively for 3-way valves. Spool action is most popular for oil hydraulics and compressed air 4-way valves. Electrical and fluid circuitry is generally the same for valves of either construction.

Part A Figure 1-8. 2-Way Spool Valves. Most manufacturers offer 2-way valves with only single solenoid construction, spring return. A few double solenoid models having two positions may be available.

Three-position double-solenoid 2-way valves normally are not available, since there is no practical use for a center neutral position on a shut-off valve; it is either open or closed.

Part B - Figure 1-8. 2-Way Poppet Valves. Mounting requirements may vary with the brand and nature of the valve. Some poppet valves are constructed so they can be mounted in any position, while others must be mounted with the solenoid vertically upward in order to function properly or at all. If no specific mounting information is available, the best practice is always to mount a valve of this type with solenoid up.

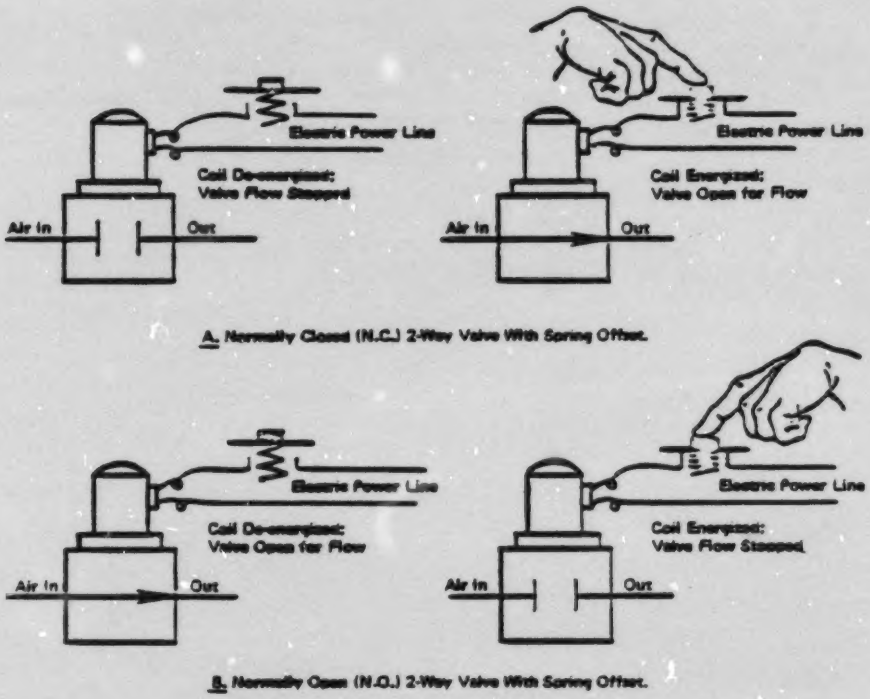


FIGURE 1-9. Examples of the action of 2-way solenoid valves of the N.O. (normally open) and N.C. (normally closed) types.

Figure 1-9. Action of 2-Way Solenoid Valves. Two-way valves may be either N.C. (normally closed) or N.O. (normally open). This nomenclature refers to the flow passage through the valve when its solenoid is de-energized.

Part A of this figure shows that a N.C. valve, when de-energized, blocks fluid flow through it. When energized, fluid will flow through it in the direction of inlet to outlet or in the direction of the flow arrow marked on the valve body (if one is present). Part B of the figure shows that a N.O. valve, when de-

energized, will pass fluid flow in the direction of its flow arrow, and will be closed to flow when energized.

Important Note. When selecting a 2-way poppet valve for a given application make sure you understand its flow characteristics. There are important variations between brands. Some of them will permit reverse flow (similar to check valve action) even when they are closed to flow in the forward direction. Some will not pass flow at all, or with severe restriction, in the reverse direction even when they are open to free flow in the forward direction. Some have large connections but small diameter internal orifices.

Choice of a N.O. or N.C. 2-way valve depends on the fluid action desired when the valve is energized. Sometimes either type could be used if tied in with the proper electrical contacts, and the choice may be made to obtain "fail-safe" operation; to put the fluid circuit in a safe condition if an electrical failure should occur. In most applications a N.C. valve would be preferred, as it would close, cutting off the fluid flow, if control current should fail or a solenoid coil should burn out. A notable exception is solenoid venting of a pump relief valve, in which a N.O. valve is ordinarily used. In case of electrical failure, the pump would be unloaded. See Figure 5-4, Page 95.

Valve type may also be selected on the basis of length of its on and off periods. A type is selected which requires energization over the minimum length of time.

4. Poppet-Type 3-Way Valves.

Figure 1-8. This figure may also be used to illustrate the general appearance of a 3-way valve. Such a valve will, of course, have three main ports. Electrical circuitry for 3-way poppet valves is the same as has been discussed for sliding spool 3-way valves. See Figure 1-7.

5. Directional Control Valves — 5-Way.

Ordinarily used only on compressed air, seldom on hydraulics. Their appearance may be identical to that of a 4-way of the same brand. They are constructed to have two pressure inlets, two cylinder ports, and one exhaust port. Their purpose is to operate a double-acting cylinder from a different level of input pressure in each direction. Many brands of dual exhaust air valves are suitable for 5-way service by reversing their inlet and exhaust connections, using the dual exhaust ports for dual inlet ports, and the single inlet port for a single exhaust port. For further description of 5-way valves and their applications, see "Industrial Fluid Power — Volume 1"*, Chapter 4.

Electrical circuitry for operation of 5-way valves is the same as would be used for 4-way valves of the same type.

6. Orienting Cylinder Direction with Valve Position.

If, after making an installation, the cylinder moves in the wrong direction in response to a given electrical signal, its motion can be re-oriented in relation to the electrical circuit as follows:

On double solenoid valves, interchange fluid connections either at the valve or at the cylinder ports, or, interchange wiring to the two solenoid coils.

On single solenoid valves, interchange fluid connections at the valve or the cylinder ports.

On 3-way valves operating a single-acting cylinder, the normal porting of the valve must be changed. If a N.O. valve change to N.C., etc. When using a 4-way valve in 3-way service this is accomplished by connecting cylinder line to opposite cylinder port on the valve, while plugging the original cylinder port.

* *Textbook available from Womack Educational Publications.*

PROGRAM IEM

SELF-HELP EXAM

TASK = 212 - 1

DIRECTIONS:

THE PURPOSE OF THIS EXAM IS TO DETERMINE WHETHER OR NOT YOU HAVE UNDERSTOOD THE INFORMATION ON fluid components of robotic systems.

Each of the questions or incomplete statements below is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A,B,C or D) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer 10 out of 10 items correctly, 100 %.

EVALUATION SHEET

1. Draw the graphic symbol for a solenoid operated 4-way valve.

2. Draw the graphic symbol for a double acting solenoid 4-way valve.

3. Identify the action of a 2-way valve.

4. The main difference between air and hydraulic circuits is

INTERMEDIATE OBJECTIVE 2

Identify common electrical sensors.

LEARNING STEPS (Activities)

1. Read the information sheet cited in Resource #1 to identify the electrical components of a robotic system.
2. Perform self help quiz identified in Resource #2 to assure your mastery of the subject.
3. Complete the criterion exam for the terminal performance objective.

RESOURCES

1. Information Sheet #2 starts on page 16.
2. Self-help quiz #2 begins on page
3. See your instructor for the needed TPO exam.

COMMON ELECTRICAL SENSORS (SWITCHES)

In the descriptions of switches and other electrical components to follow we have tried to give a brief and very general description of the most important components that are useful in controlling fluid power. Because of the wide variety of such components on the market we recommend the student or designer obtain amplified descriptions from electrical catalogs. Appearance of components may vary widely from the sketches shown here, according to brand, and it is beyond the scope of this text to provide a comprehensive description of all components available.

1. Definition of a Sensor.

The context in which the term "sensor" is used in this book includes any device which produces an electrical switching signal, triggered by some action of the fluid circuit. Three distinct classes of sensors are commonly used: (a), Switches which produce a switching signal when mechanically actuated by a moving part of a fluid cylinder or other machine member. Various types of limit switches fall into this category. (b), Pressure switches which give a switching signal in response to a rise or fall of fluid pressure in a pipe. Most of these are adjustable, allowing them to be pre-set to switch precisely at a given pressure level. (c), Manually operated switches actuated by an operator, such as pushbuttons and foot switches. Certain other sensors are available such as photoelectric, sonic, proximity, etc., but are less often used in fluid power applications.

2. Duty Rating of Switches.

From past experience it has been found that switches are often the first point of breakdown in an electrically controlled machine; it is very important to select them according to the duty expected of them. The use of low priced, non-enclosed, light-duty switches can only be justified in those applications where operation will be infrequent and where there is no danger of contamination from water or oil, or where switch cost is a very important factor. Good switches add to the original cost but will pay for themselves many times over with their long life and reliable operation. When selecting switches for machines operating on a continuous basis, where an electrical breakdown would be costly, the heavy-duty industrial type should always be used. It is best to obtain the advice of your electrical distributor as to the quality of switch to be purchased according to the life expectancy of the machine on which it will be used.

But even switches of the highest quality will not give reliable service unless properly mounted, and actuated with carefully designed cams. The main points to be observed are:

(a). Machine cams which actuate the switch should be designed so they contact the switch roller at the proper angle, and for high speed operation their leading edge should be shaped to give uniform acceleration to the switch arm. Cams which override the switch arm should be designed so the switch arm cannot snap back freely. See Page 115 for detailed information.

(b). It almost goes without saying that a switch should be mounted so it will be protected from physical damage if a cylinder should get out of control and override it.

(c). Switches should not be operated beyond the normal recommended travel of the actuator arm. This causes added internal stress which shortens the switch life.

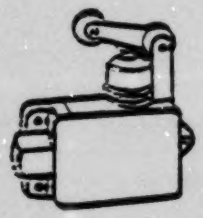
Standard Limit Switch Sensors, Figure 1-10.

Limit switch types are not limited to those shown in this figure. A complete catalog of electrical switches should be consulted for selecting the types of actuator most convenient for a given installation.

Part A, Figure 1-10. The basic snap-action switch is available with many different actuators, and is relatively inexpensive. It is intended for light duty service in a protected environment. Although the switch contacts are enclosed, they are not sealed against entry of water and oil, and the electric terminals are exposed. For hydraulic fluid power the basic switch is primarily useful on experimental or temporary set-ups, but seldom suitable on permanent, heavy-duty installations.

A. Basic light-duty switch, non-enclosed, with roller actuator.

B. Light-duty switch in protective housing. Pin actuator illustrated.



C. Light-duty switch in protective housing. Roller actuator illustrated.

D. Heavy-duty industrial type limit switch illustrated with roller arm actuator.

FIGURE 1-10. Examples of Limit Switches Having Standard Action with Spring Returned Contacts.

Parts B and C, Figure 1-10. The light-duty basic switch element is supplied with several different actuators in a water and oil-tight enclosure. The electrical terminals as well as the contacts are completely protected. This makes it environmentally suitable for most fluid power installations. The classification of "light-duty" for these switches does not infer they are inferior in quality. They are specifically designed for a good balance between cost and contact service. Their best application is on those installations subjected to a moderate number of switching cycles, and where the occasional replacement of a switch is not any problem. Size may also be a factor.

Part D, Figure 1-10. Heavy-duty industrial limit switches should be used on machines where the utmost in reliability is important; where a breakdown in a switch would be costly from the standpoint of lost production time. These industrial switches are considerably more expensive than the light-duty switches. They are also larger, which may present a mounting problem where space is limited. The designer must weigh advantages against disadvantages in selecting switches most suitable for a given machine. Plug-in switches are available which can be quickly replaced by removing only two screws.

CAUTION! Limit switches should always be mounted in such a manner that they cannot be damaged if the machine should accidentally overtravel, which might happen if a solenoid coil should burn out or if control current should fail. Switch mounting brackets should be designed to allow an adjustment in switch positioning.

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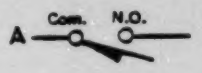
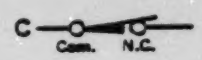
4. Limit Switch Contacts and Terminology.

The diagrams in the chart on this page show the proper way of drawing limit switch contacts on schematic diagrams. When properly drawn, the symbols provide important information on switch action and type. An important clue is the solid triangle drawn on the switch arm. A moving cam works against this surface to open or close the contacts. Abbreviations such as N.O., N.C., Com., SPST, SPDT, etc., may be placed adjacent to the contacts for assistance to the reader in identifying the contact action. Abbreviations are defined in the chart. If the term "double pole" is used with any of the following, it indicates two separate sets of switch contacts in the same housing with a common actuator.

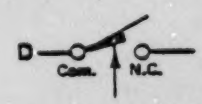


A. SPST (single pole, single throw) N.O. (normally open) set of contacts. Usually drawn in their "normal" state which is open, except when there is a reason for showing them in the actuated state.

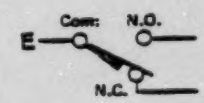
B. Same contacts as Part A, drawn in their actuated state. The side arrow shows they are held closed by a cam before the start of a cycle or during standby periods. However, the position of the solid triangle on the arm, pointing away from the contacts, indicates their normal type and state as N.O. (normally open).



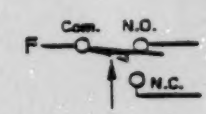
C. SPST (single pole, single throw) N.C. (normally closed) set of contacts, shown in their "normal" (non-actuated) state. The placement of the solid triangle shows that a cam would open them.



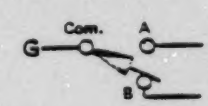
D. Same contacts as Part C, drawn in their actuated state. The side arrow shows they are held open by a cam before the start of a cycle or during standby periods. However, the position of the solid triangle on the arm indicates their normal type and state as N.C.



E. SPDT (single pole, double throw) contacts. Sometimes called "transfer" contacts. Placement of the solid triangle on the arm indicates which is the N.O. and which the N.C. circuit. It indicates also that the contacts are in their "normal" state.



F. Same contacts as Part E, drawn in their actuated state. The side arrow shows they are mechanically held in an abnormal state, but the solid triangle on the arm shows their normal state.



G. SPDT contacts on a maintained type (no spring) switch as in Figure 1-17, Part B. A solid triangle on both sides of the arm indicates it must be actuated in both directions. There is no N.O. or N.C. marking on its terminals because it has no "normal" condition.

Note: Abbreviations next to contacts, Com., N.O., and N.C., indicate common, normally open, and normally closed respectively.

FIGURE 1-11. Contact Arrangements for Limit Switch Sensors.

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Switch contacts which have a return spring are said to be in their "normal" state when not mechanically actuated. Contacts should always be drawn in their normal state on diagrams except when a cam is holding them actuated during a standby period or between cycles. Examples will be found on diagrams in this book showing a switch in actuated condition where a cylinder, returning to home position, ends the cycle by "standing" on the switch. As soon as the cylinder has moved a short distance from home position the switch can return to its normal state.

In Figure 1-11, Part A, for example, the symbol for N.O. (normally open) switch is shown as it would ususily be drawn. But if it is held in an actuated condition at the end of a cycle, it should be drawn as indicated in Part B of the illustration.

If switch contacts must be actuated in both directions, as for example a toggle-type, over-center switch, there is no "normal" position for the contacts. On the schematic, they should be drawn in the state they will be in at the end of a cycle. Their terminals may be unmarked on the switch except for the common terminal, and terminals on the drawing should likewise be left unmarked. Part G of the drawing is an example of such a switch.

Little used but sometimes available are DPDT (double pole, double throw) switches having two independent sets of transfer type contacts in the same housing, operated by the same actuator.

FIGURE 1-12. Standard Limit Switch Fitted With One-Way Roller Actuator.

5. One-Way Roller Limit Switch.

Figure 1-12. An example of a non-enclosed limit switch having a one-way roller actuator. The actuator arm has a knee joint which folds out of the way of a machine cam approaching from the left without actuating the switch contacts. But when a cam approaches from the right, the knee joint does not bend, and the switch contacts are actuated.

This one-way action is useful on switches to be actuated at an intermediate point in a cylinder stroke. The returning cam can pass over the switch without producing a second, and unwanted signal.

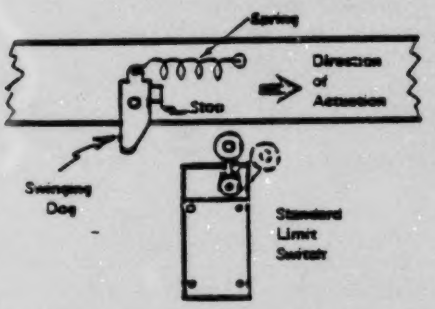


FIGURE 1-13. A spring loaded machine cam can be constructed to have a 1-way action on a standard limit switch.

Light-duty actuators of this type should be used at machine speeds of less than 50 feet per minute to obtain reasonable life. The shape of actuating cams should follow the recommendations on Pages 114 to 116.

Heavy-duty industrial limit switches may be purchased with a partial roller rotationally spring loaded, which gives the same one-way action described above. Or, a standard limit switch may be used, operated with a spring-loaded or gravity return dog hinged to the moving machine member. Figure 1-13.

In this illustration, the dog, when traveling toward the right will actuate the switch contacts, but when traveling toward the left, will fold out of the way.

Further details of one-way roller action will be found on Pages 115 and 116.

Impulse Limit Switches Help Solve Difficult Circuit Problems

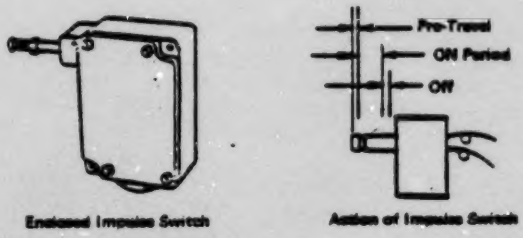


FIGURE 1-14.
A special limit switch with one-way impulse action will sometimes help solve an otherwise difficult circuitry problem.

6. Impulse Limit Switch.

Figure 1-14. The one-way impulse switch illustrated above is a special switch available to the designer for simplifying difficult circuit problems. Where applicable, it can eliminate holding relays and their associated wiring. However, it is subject to certain limitations described below, and can only be used in circuits especially designed for it.

The action is as follows: A switching signal is produced only while the plunger is traveling inward. Signal cuts off as the end of the plunger travel is reached, and remains off during return travel. Usually has one set of "transfer" contacts with one N.O. and one N.C. circuit. To illustrate the action, as soon as the plunger starts its inward travel the N.O. contacts close and remain closed until full inward travel has been completed. These contacts then open and remain open as long as the plunger remains depressed. They also remain open during return travel and when the plunger is released and returns by internal spring force. Thus, a short duration "make" is produced on the N.O. switch terminal and a short duration "break" on the N.C. terminal.

Switch Limitations. The faster its stem is actuated the shorter the switching impulse. On high speed mechanisms the impulse may be so short as to be unreliable for shifting a fluid power valve. Normally, 50 feet per minute is the maximum actuation speed, although operation may be successful up to 100 feet per minute. If machine travel is too fast for an impulse switch, the solid state impulse circuit in Chapter 6 may be used, or standard components and circuitry can be used. Any control function possible with impulse switches can be duplicated with standard components by adding holding relays.

Mounting is critical. The switch must be accurately positioned to within 1/64th of an inch. The traveling mechanism must carry the stem to full depth in order to cut off the switching signal, but must not overtravel far enough to damage the switch. Impulse switches should never be used on loose, non-precision mechanisms which might not stop precisely at the same place every time.

7. Pressure Switch Sensors.

Figure 1-15. A pressure switch is teed into the fluid line, which may be air, hydraulic, or vacuum. Its working element responds to a rise or fall of fluid pressure to open or close a set of electrical contacts when a certain pressure level is reached. Most pressure switches are adjustable over a limited range of fluid pressure, and may be purchased for the range desired.

The pressure sensing element is often a Bourdon tube, similar to that used in some pressure gauges. It is a curled tube of bronze, steel, or stainless steel, closed at one end,

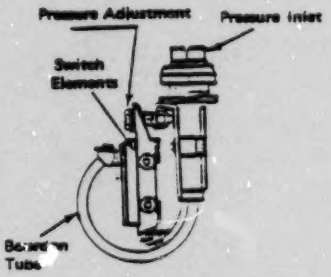


FIGURE 1-15. Bourdon Tube Pressure Switch.

into which fluid pressure is introduced. Internal fluid pressure tends to "uncurl" the tube. This uncurling movement is linked to a set of contacts. Other sensing elements may also be used, as a spring-loaded bellows of brass, bronze, steel, or stainless steel for low pressure ranges, or a spring loaded piston for high pressure ranges. And for very high pressure ranges, two spring loaded pistons of slightly different areas produce opposing forces. The low range resultant force from these pistons is applied to a sensing mechanism operating a set of electrical contacts.

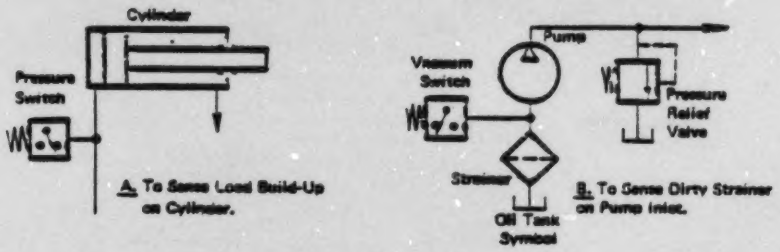


FIGURE 1-16. Examples of Pressure Switch Applications.

Figure 1-16. Pressure switches may be installed in various parts of a fluid system to produce an electrical switching signal in response to a rise or fall in fluid pressure. One of the most useful applications is shown in Part A. The pressure switch, of suitable range, is teed into a cylinder line to give a switching signal when load against the cylinder piston has caused fluid pressure behind the piston to rise to the adjustment setting of the pressure switch. This switching signal can be used to reverse the cylinder travel or to start a second action in an automatic cycle.

In Part B, a vacuum switch is teed into the inlet (suction) side of a hydraulic pump. Its contacts may be tied into an electric warning signal if pump suction should rise to a dangerous level due to build-up of dirt on the inlet strainer. Other examples of pressure switch use are shown in later chapters.

Terminology. Switching contacts in a pressure switch are sometimes called "make-on-rise" or "break-on-rise". These terms describe switch action as fluid pressure increases. Comparing this terminology with that of limit switches, "make-on-rise" is equivalent to N.O. (normally open), and "break-on-rise" is equivalent to N.C. (normally closed).

B. Toggle-Type Switches.

Toggle action, as applied to switches, may be described as an over-center snap action that rapidly opens or closes a set of contacts. It further implies that there is no return spring; the contacts must be mechanically actuated from one position to the other. They do not have a "normal" state to which they return by spring force after external actuating force has been removed.

Several terms are used to describe this kind of switch action: "Flip-flop" is used in fluidics to describe a similar action. "Maintained" action is another term frequently used.

Figure 1-17. Several types of "toggle" or "maintained" action switches are available for electrical control of fluid power. Part A shows a miniature switch designed for finger operation, usually to be

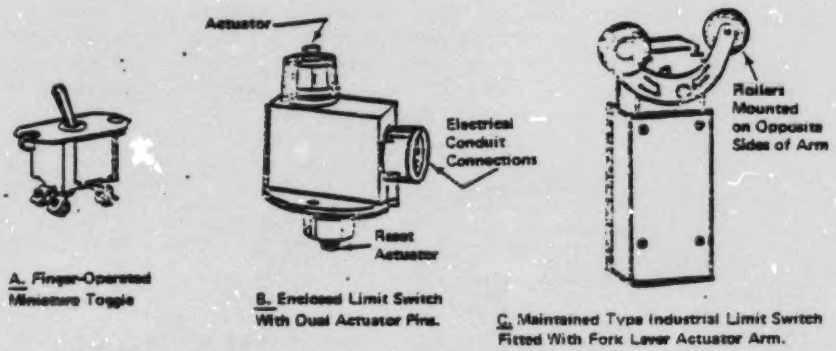

Actuator
Electrical Conduit Connections
Reset Actuator
Rollers Mounted on Opposite Sides of Arm
A. Finger-Operated Miniature Toggle
B. Enclosed Limit Switch With Dual Actuator Pins.
C. Maintained Type Industrial Limit Switch Fitted With Fork Lever Actuator Arm.

FIGURE 1-17. Examples of Switches Having "Maintained" or "Toggle-Type" Action.

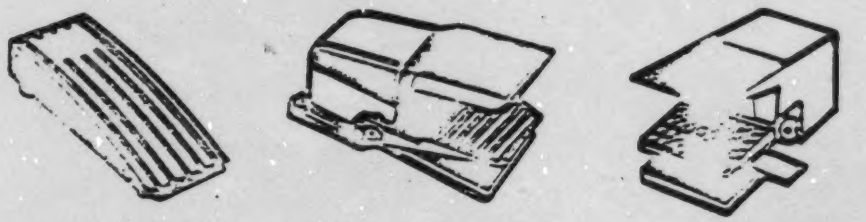
mounted on a control panel. It can also be mounted on a machine for actuation by a moving cam, subject to certain operating limitations described in a later chapter, Page 58, and must be protected against overrun by the cylinder. Its use as a cam actuated switch should be limited to light duty and experimental applications, as it is not built ruggedly enough to stand up long in this service. True toggle switches, with their over-center action, are necessarily limited to two working positions. Similar switches are available having a center neutral, and these usually have double toggle action, or simply a spring loaded detent.

Part B shows a maintained type switch in protected enclosure. Two stems, one on top, the other on the bottom, toggle the contacts from one position to the other. There is no internal return spring. The contacts remain in the last position to which they were toggled until a thrust from the opposite stem shifts them to their other position.

Part C shows a heavy duty industrial limit switch fitted with a fork lever actuator arm. The basic switch to which this arm is fitted must have a maintained action; no spring return. The most often used fork lever arm used in fluid power has two rollers mounted on opposite sides of the lever. Each roller is actuated by a different cam on the machine. This is known as an "offset" type of fork lever. An alternate fork lever is available with both rollers mounted on the same side of the lever, and may be used on applications where both rollers are to be actuated by the same cam. Diagrams in Chapter 3 show how the fork lever switch may be used.

9. Foot Operated Switches.

Figure 1-18, Part A shows a light duty foot switch which may be actuated by an operator's foot, knee, hand, elbow, or arm. It is available with choice of several operating arrangements including: (a), foot actuation with: spring return, either N.O., N.C., or transfer contacts; (b), with pedal hinged at the center, with centering springs or center detent, and with two sets of contacts for toe (forward) or heel (backward) operation for switching two different circuits; (c), two contact sets at different depths of pedal travel: the first pedal movement actuates the first set, then as the pedal is pressed further, the second set is also actuated. Light duty switches of this general type are not usually sealed; they are primar-



A. Light-Duty Foot Switch in Open-Type Housing.

B. Light-Duty Switch Element Enclosed in Watertight Housing.

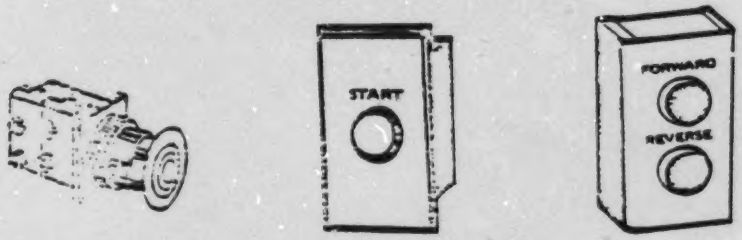
C. Heavy-Duty Industrial Foot Switch With Toe Guard & Latch.

FIGURE 1-18. Examples of Foot Operated Switches.

ily for portable use, and are connected to the main control box with rubber covered cord or flexible cable.

Part B illustrates one brand of light duty switching element enclosed in a ruggedly constructed iron housing sealed against entry of water and oil. Available with or without a guard to safeguard against actuation by a falling object. Enclosed switches usually have an electrical conduit connection sealed for permanent installation, but may be installed for portable use by using a waterproof cable properly sealed at the conduit opening.

Heavy duty models, Part C, have rugged frame, usually cast iron, to resist a considerable amount of abuse. Switching elements have a high amperage rating and are completely enclosed against entry of dirt, water, and oil. They may be obtained with or without toe guard and with or without latch. Latch locks treadle down after it is depressed. Foot pressure on the latch lever unlocks the treadle. Some latching switches unlock by pressing the treadle a second time. Wiring is through a conduit connection.



A. Industrial Pushbutton for Panel Mounting.

B. Momentary Pushbutton in Enclosure.

C. Momentary or Maintained Pushbutton in Enclosure.

FIGURE 1-19. Examples of Electrical Pushbuttons.

10. Electrical Pushbuttons.

Figure 1-19, Part A pictures an industrial type momentary pushbutton designed for mounting in a control console. This illustration shows a stack up of two sections giving a total of four independent sets of contacts, choice of N.O. or N.C. Two-circuit type contacts are made by combining one N.O. and

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one N.C. set of contacts. Any reasonable number of sections can be stacked together, although the required operating force increases with the number of sections stacked. In fluid power control, except on extremely involved circuitry, seldom more than one section is required. Push knobs can be obtained in several colors for color coding; some brands can be purchased with lighted buttons. A choice of knobs is also available from small diameter miniature knobs to large diameter mushroom knobs. A further choice is with key locks to prevent unauthorized operation.

In Part B, individual enclosures can be used for pushbuttons which are not part of a control console. The buttons pictured in Fig. 1-A are mounted in enclosures designed for one to four or more buttons.

Part C. Pushbutton pairs are of two types: Momentary buttons, each button with spring return, for such operations as "Forward - Reverse", "Up - Down", "Start - Stop", and others, and maintained buttons which are mechanically interlocked one with the other. Pressing one button locks it in while unlatching and releasing the opposite button. Electrical circuitry is often much simpler with maintained, mechanically interlocked buttons, but momentary buttons have the advantage of remote control capability from several control points.

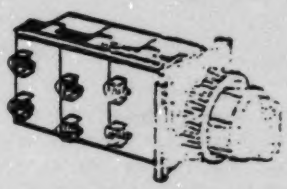
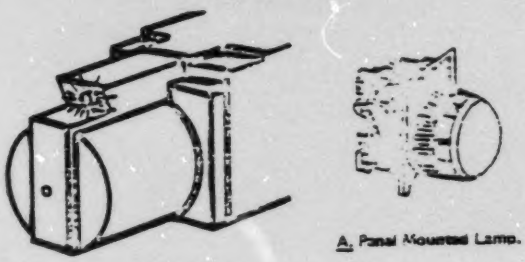


FIGURE 1-20. Industrial Rotary Switch.

11. Rotary Selector Switches.

Figure 1-20. For electrical control consoles this type of rotary switch is normally used. It is available in 2-position and 3-position models and with any reasonable number of contact sets by stacking sections on the basic switch. The illustration pictures a 3-section stack. A choice is offered of 2-position, spring return, 3-position spring centered or detented. Available also with key lock.

Where the above switch is not adequate, rotary switches for the electronic industry are available with up to 25 or more rotary positions.



A. Panel Mounted Lamp.

B. Lamp on Solenoid Coil.

FIGURE 1-21. Indicator Lamps.

12. Indicator Lamps.

An indicator lamp permanently wired across each solenoid valve coil provides the troubleshooter with a quick means of pinpointing trouble in event of an electrical breakdown. If mounted on an operator's panel they should be mounted in order of their actuation. Since they are not a functional part of the electrical circuit, their addition is left to the discretion of the designer.

On spring centered and spring return solenoid valves, the lamps may be wired directly across each solenoid coil. For addition to momentary type 2-position valves, see Page 133.

Most hydraulic valve manufacturers can now supply their solenoid valves with indicator lamps built into the solenoid assembly. This feature costs a little extra when the valves are purchased but is valuable as a troubleshooting aid to quickly determine whether or not the electrical circuit is working.

OTHER ELECTRICAL COMPONENTS

In this section we have selected for description a few of the many electrical devices available to the circuit designer. Those selected are the ones most often used in electrical control of fluid power. They are available from many sources and may sometimes vary in physical size and appearance from the illustrations shown, while still having identical electrical action.

1. Relay.

A relay consists of an electromagnet with a moving armature. One or more sets of electrical contacts are actuated by closure of the armature as the relay coil is energized. These contacts are said to be in their "normal" state when the magnet coil is de-energized, and in their "actuated" state when the coil is energized.

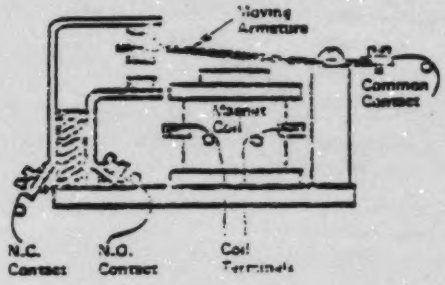


FIGURE 1-22A. Electrical Relay Shown With Coil De-energized.

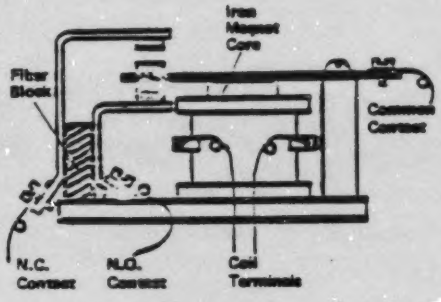
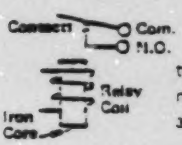


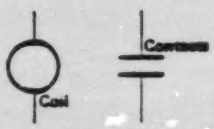
FIGURE 1-22B. Same relay with coil energized. Contacts have changed position.

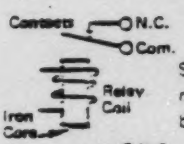
Types of Relay Contacts. Industrial relays having heavy-duty contacts are usually furnished with only two types of contacts — normally open and normally closed. Several sets of either type can be mounted on one coil and armature structure. Proper marking of coil and contacts is shown on Page 32.



Normally Open (N.C.) Contacts

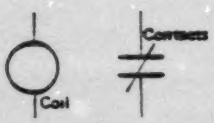
When the relay coil is energized, the contacts close. Picture symbol of relay is shown to the left, standard schematic symbol to the right, with a circle for the coil magnet and a set of parallel bars representing the N.O. contacts.

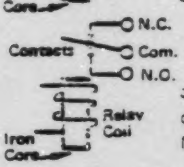




Normally Closed (N.C.) Contacts

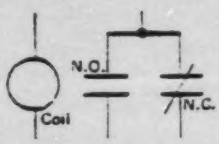
When the relay coil is energized, the contacts open. Standard symbol for schematic diagrams is shown to the right, with a circle for the coil magnet and a set of parallel bars with a slash showing the contacts are N.C. type.





Transfer Type Contacts

Transfer type contacts have single pole double throw action. While available on some relays, they are constructed on an industrial relay by combining a N.O. set with a N.C. set of contacts as shown in the diagram to the right.



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2. Relay Applications.

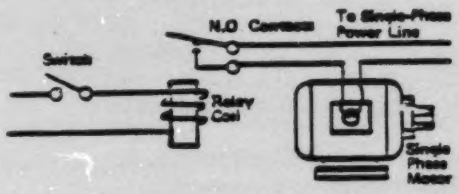
The designer should use good judgement in choosing relays for a control circuit, according to the duty expected of them. The sharp impact of the relay armature tends to be destructive, so any relay will have a definite life expectancy. Light-duty relays, with their economy of first cost, may be a wise choice for experimental circuitry and possibly on machines which are operated very occasionally. But on industrial machines which operate on a high duty cycle and where long and trouble-free life is demanded, heavy-duty industrial relays should always be used. While their first cost is higher, they will pay for themselves many times over by reducing the service problems.

Plug-in relays are available and are useful for compact console construction and to facilitate replacement of relays. They have an advantage of being sealed against dirt and water. But they are usually light-duty relays which are intended only for low-current control circuits.

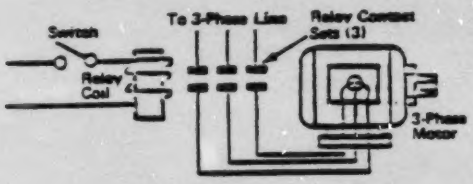
"Contactor" is another term for a relay. In common usage a contactor is considered to be primarily a power handling device for switching components which operate at a high power level, and a relay is usually considered to be a control device operating at a low power level. (Usually low amperage).

It almost goes without saying that the designer in ordering relays must specify the number of contact sets and their type, that is, N.O. (normally open) or N.C. (normally closed). He must also specify the coil voltage and frequency (if for A-C). He must also make certain that the contact sets on the chosen model have sufficient rating for the voltage and current to be handled.

Figure 1-23. In the four application sketches here and on the following page are shown the more important uses of relays on machines using fluid power. Relays are essential on all electrically controlled fluid power machines except those on very simple applications.



A. Relay Operating a Single-Phase Device.



B. Relay Operating a 3-Phase Device.

FIGURE 1-23A. As a power handling device, relays and contactors may be used to switch high power single-phase and 3-phase loads.

Figure 1-23A. Power Handling. Contactors rather than control relays are normally used for making and breaking high current loads. The relay coil operates on a very low power level and can be controlled with small limit switches and pushbuttons. Assemblies of several sets of contacts can be obtained on each contactor to switch single-phase or 3-phase loads at the same or a different voltage than used on the relay coil.

Examples of contactors on 3-phase loads are magnetic motor starters for electric motors driving air compressors, hydraulic pumps, or drilling units. This application is discussed on Pages 150 to 153, Chapter 9.

Electric immersion heater elements are controlled with thermal switches through contactors. Heaters may be installed under the oil level of hydraulic tanks for overnight use in cold climates.

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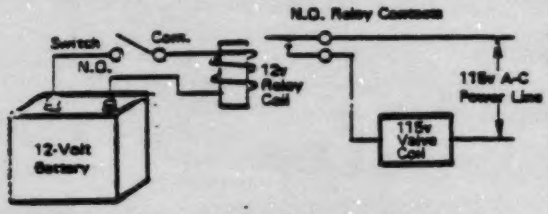


FIGURE 1-23B. A relay or contactor may be used to "interface" from one type of power to another.

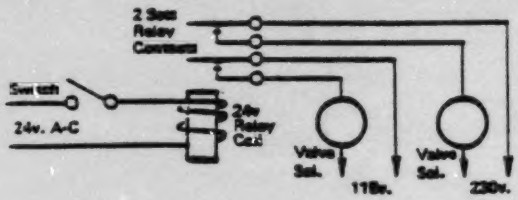


FIGURE 1-23C. Several independent power circuits may be simultaneously switched with relays.

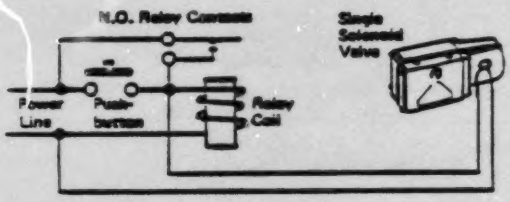


FIGURE 1-23D. Current can be maintained on spring return or spring centered solenoid valves.

Figure 1-23B. Transition. Relays or contactors may be used as intermediary devices for coupling two circuits which operate at different voltage or frequency levels, between D-C and A-C circuits, or between single-phase and 3-phase. They transmit electrical signals from one circuit to the other while keeping the two circuits from intermingling. In this sense a relay is acting as an "interface" device for a purpose similar to that described for fluidic interface devices. See Page 173.

Figure 1-23C. Isolation. Relays are not only used to isolate a coil circuit from a contact circuit, but may be used to isolate and switch loads of different characteristics. As illustrated here, two loads, one operating at 115 volts, the other at 230 volts are simultaneously switched with one relay. The relay may obtain its coil voltage from either of these two sources or from an entirely different source.

Figure 1-23D. Electrical Lock-In. An important use of a relay is to hold current on a solenoid valve after it has been momentarily energized from a pushbutton. To release the relay and solenoid valve, the power circuit must be momentarily interrupted. Details are given in the following description and in many circuits to follow, starting with Figure 3-3, Page 40.

3. Holding Relay Principle.

Any relay or contactor becomes a "holding relay" when wired through its own contacts in such a way that the armature will lock closed electrically after the coil is momentarily energized. The locking action is obtained by holding current on the coil and not by mechanical action as is the case with certain special relays which have a mechanical latch to lock the armature closed, and have a second coil to release the armature when momentarily energized. These latter are not classed as holding relays; they are usually termed "latching relays". An example of their use is on Page 133, Figure 7-22.

In electrical diagrams holding relays are often called "control relays" and are designated with Symbols 1-CR, 2-CR, 3-CR, etc. Contacts operated by their coils are designated in a similar manner as explained on Page 32.

The lock-in action of a holding relay is one of the most important principles to understand and use when designing electrical control circuits. It is especially useful for operating spring action solenoid valves — spring return and spring centered — both air and hydraulic, from momentary pushbuttons. It is used almost universally in magnetic motor starters because it will permit the starter to be remotely operated from more than one location; mechanical lock-in start/stop buttons are limited to 1-point control.

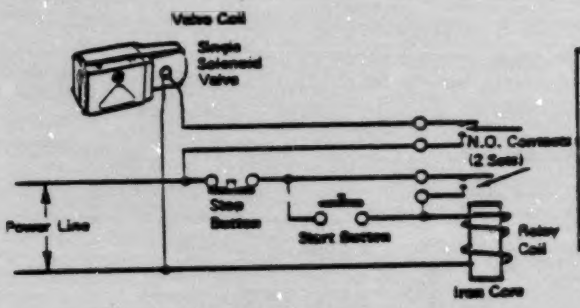


FIGURE 1-24. Electrical lock-in action of a "holding relay" in operation of a single solenoid air or hydraulic valve.

Figure 1-24. Holding relay action is shown pictorially in this diagram. Later, on Page 40, the holding relay is shown with standard graphic symbols in Figure 3-3.

The purpose of using a holding relay to operate a spring action solenoid valve is to keep current on the valve coil — to keep its spool shifted — even though the initial starting signal is not maintained. Circuit action in the above diagram is as follows:

When the "Start" pushbutton is pressed, the relay coil becomes energized, which closes both sets of contacts. The lower set — the holding contacts — now by-passes the pushbutton. The button can be released and the relay coil remains energized from current supplied through these lower contacts. The solenoid valve receives its current through the upper set of contacts. To release the relay coil and solenoid valve, the holding circuit must be interrupted by momentarily pressing the "Stop" pushbutton. This stops current flow to the coil, de-energizing the magnet, and all contacts open by spring action.

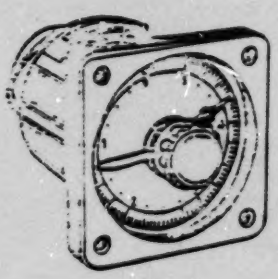


FIGURE 1-25. Adjustable Re-Set Timer (Panel Mounted Type).

4. Re-Set Electrical Timers.

Figure 1-25. May be used in a fluid power control system to delay any action such as start-up of a cylinder, or to establish a "dwell" period at one end of a cylinder travel before start-up in the opposite direction. This delay or dwell can range from a few seconds up to several hours in the case of a curing cycle.

A re-set timer is one which starts timing from zero reference when energized. At the end of the set time period its contacts are activated. When the timer motor is de-energized, an internal spring returns the mechanism to zero time reference ready for the next cycle, and re-sets the contacts to their original condition. It may have any reasonable number of independent contact sets actuated from one timing motor. It is available in a wide selection of time delay ranges.

Other manufacturers may offer re-set electrical timers having an appearance quite different from that shown in the illustration but having essentially the same electrical action. Since there is such a wide variety of timers on the market, the designer should, if considering the use of one, obtain catalogs from several manufacturers to select the one most suitable for his application.

Motor driven timers use a small self-starting synchronous electric motor as a timing element. Others may use electronic or solid state components, with voltage build-up on a capacitor as the timing principle. Still others may use a restricted air flow through an adjustable orifice to obtain a time delay.

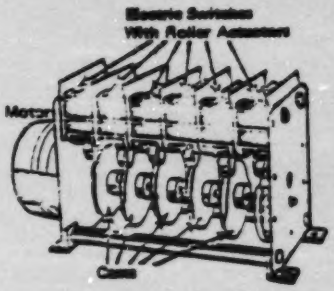


FIGURE 1-26. Program Timer

5. Program Timers.

Figure 1-26. A program timer has a set of cams and switches operated by the rotation of a small synchronous electric motor. This kind of timer does not re-set when de-energized. It picks up from where it previously stopped. It runs always in one direction and usually is arranged to stop through action of internal switching at the end of each complete revolution of the cams. When energized again, either from a momentary or maintained signal, it runs through another complete revolution and stops.

Its application to control of fluid power cylinders is to successively energize and de-energize several solenoid valves in the correct time sequence. See hydraulic circuit on Page 119.

In the illustration the timer is shown with several circular cam assemblies, each of which actuates a lever arm limit switch having one set of transfer type contacts. Each cam assembly has "split" cams; that is, two similar cams are mounted next to one another. Each of these cams can be rotated on the shaft with respect to the other to lengthen or shorten the "ON" or "OFF" time of the associated limit switch. Each cam assembly (of two split cams) can also be positioned rotationally with respect to other cam assemblies to operate the limit switches in the correct sequence.

Timers may be constructed by the user to suit special applications. Several circuits are shown on Pages 126 and 127 to cause the drive motor to stop automatically at the end of each revolution.

Through the use of program timers, an otherwise complicated electrical control circuit can be reduced to very simple terms.

FIGURE 1-27. Example of Electric Counter (Panel Mounted Type).

6. Electric Counters.

Figure 1-27. An electric counter is a form of relay in which the contacts open or close after a pre-set number of electric impulses have been received. It is useful in fluid power control for stacking or packaging, in which a cylinder is to start after a certain count has been reached. Since a counter is used principally in control circuits, it is normally provided with only one set of transfer type contacts. See Page 26.

Some counters are built to automatically re-set after the desired count has been reached, and other types must be manually re-set before the start of each cycle.

BEST COPY AVAILABLE

EVALUATION SHEET

SELF-HELP QUIZ #2

- **SUBJECT:** PNEUMATIC COMPONENT SELECTION & IDENTIFICATION
- **OBJECTIVE:** To determine and identify the required components required in a pneumatic circuit
- **MATERIALS NEEDED:**
  1 - BRAT500 PNEUMATIC TRAINER
  1 - Valve
  1 - Cylinder (single action, spring return)
  1 - Air line hose with fast disconnect
- **PROCEDURE:** Select the required components to complete the pneumatic circuit shown in illustrations 1 & 2 and advance and retract a cylinder manually.

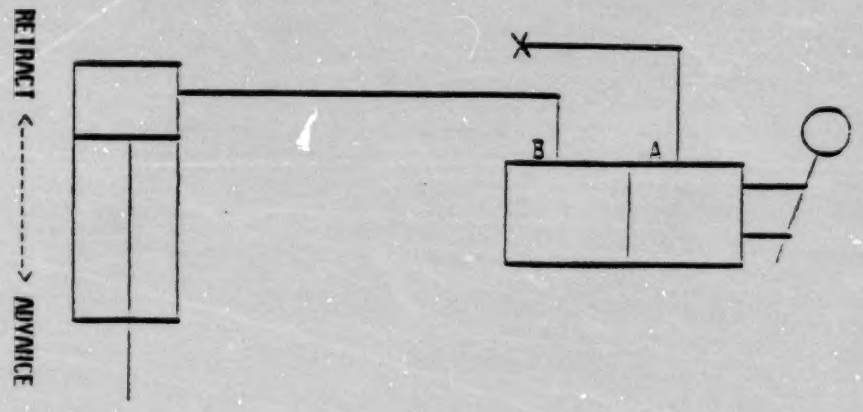


ILLUSTRATION # 1

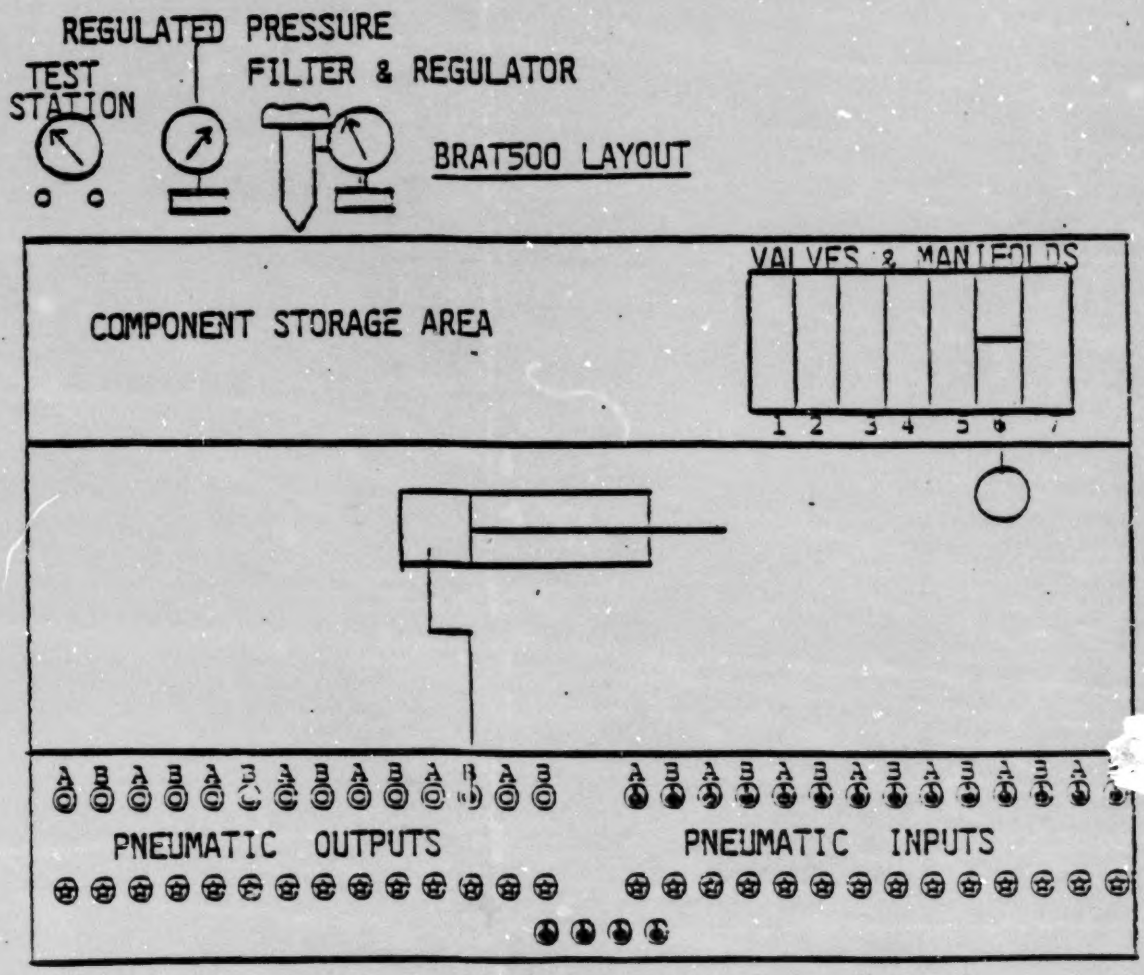
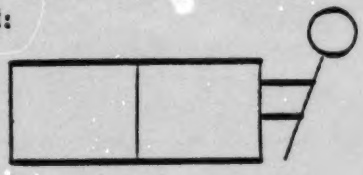


ILLUSTRATION # 2

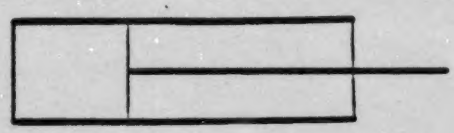
CIRCUIT TEST PROCEDURE

✓ ☐ 1 - Check all connections as indicated in illustrations

☐ 2 - Complete the symbol indicating what type of manual valve you selected:



☐ 3 - Complete the symbol for the cylinder indicating the location of the air input port:



☐ 4 - Apply 40 PSI, and move the valve lever forward. Describe what action took place:_____

_____.

☐ 5 - Move the valve lever back, what action took place:_____

_____.

☐ 6 - Once you have observed and performed the above functions, disconnect the components and return them to the storage area located on the trainer.

PROGRAM INDUSTRIAL ELECTRICAL MAINTENANCE

CRITERION EXAM

TASK = 212

DIRECTIONS:

THE PURPOSE OF THIS EXAM IS TO DETERMINE WHETHER OR NOT YOU HAVE UNDERSTOOD THE INFORMATION ON FLUID AND ELECTRICAL COMPONENTS.

Each of the questions or incomplete statements below is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A,B,C or D) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer 5 out of 5 items correctly, 100 %.

EVALUATION SHEET

CRITERION EXAM

TASK 212

Please answer the following questions:

1. What is meant by a directional valve?

2. Define electrical sensors.

3. The basic electrical component of a limit switch is_____
_____.

4. Draw the symbol for AM SPDT switch and define its "normal" position.

5. Draw the schematic diagram for a circuit which starts a motor and keeps it running after the operator removes their hands.

LAKE COUNTY AREA VOCATIONAL CENTER

COMPETENCY-BASED INDIVIDUALIZED VOCATIONAL EDUCATION INSTRUCTION

STUDENT LEARNING GUIDE

Produced By M.H. WHITMER Date 4/85

TASK: CONNECT FLUID SYSTEM VALVES

PURPOSE: You must understand how to connect fluid system valves into a circuit to achieve a desired action. The intermediate objectives under this task presents the method of connecting valves to help you achieve the needed understanding. The modern electrical maintenance person knows how to connect valves into the circuit for proper operation. Connecting valves provide the measns of control which makes the rest of the fluid system operate.

Program	Task	Est.Time	Prereq.
17.1002	213	2 hrs.	212

dmm

LEARNING CONTRACT (optional)

1. STUDENT DATA

NAME _____ SOCIAL SECURITY NUMBER _____

LENGTH OF CONTRACT (NORMAL TIME IN HOURS) _____

2. TERMINAL PERFORMANCE OBJECTIVE

Given the material, design and needed tools, you will connect pneumatic valves in a fluid system. You must score 100% on the performance checklist for this objective.

2a. INTERMEDIATE OBJECTIVE(s)

1. Connect manually piloted valves.
2. Connect pneumatic piloted valves.
3. Connect electric piloted valves.
4. Connect ~~quick~~ exhaust valves.

3. AGREEMENT

I, _____ agree to complete the above stated terminal performance requirement within _____ to _____. I further recognize that the conditions of the contract (performance and time agreement) report my ability to perform the requirements of the occupation and record my progress.

Student's Signature _____

Instructor's Signature (verifies competency) _____

Program	Task	Page
17.1002	212	2

INTERMEDIATE OBJECTIVE #1

Connect manually piloted valves.

LEARNING STEPS (Activities)

1. Review Learning Guide in Resource #1 to recall valve action.
2. Complete the procedure cited in Resource #2 to see how valves are connected.
3. Complete the circuit testing cited in Resource #2 to assure mastery of the subject.
4. Proceed to the Intermediate Objective cited in Resource #3.

RESOURCES

1. Learning Guide 212 presents valve actions and is available from your instructor.
2. Information Sheet #1 begins on page #4.
3. Procedure Sheet #1 begins on page 6 and is entitled "Manual Circuit Tes
4. Intermediate Objective #2 begins on page 7.

LABORATORY ACTIVITY 6

- SUBJECT: PNEUMATIC VALVES
- OBJECTIVE: To operate a pneumatic valve manually
- MATERIALS NEEDED: 1 - BRAT300 PNEUMATIC TRAINER
  1 - Two position lever operated valve
- PROCEDURE: Using the above listed components, set up the pneumatic circuit as shown in illustrations 1 & 2

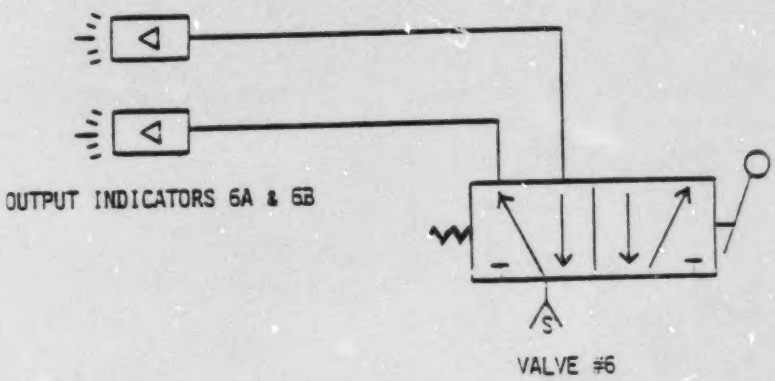


ILLUSTRATION #1

Program	Task	Page
17.1002	212	4

INFORMATION SHEET

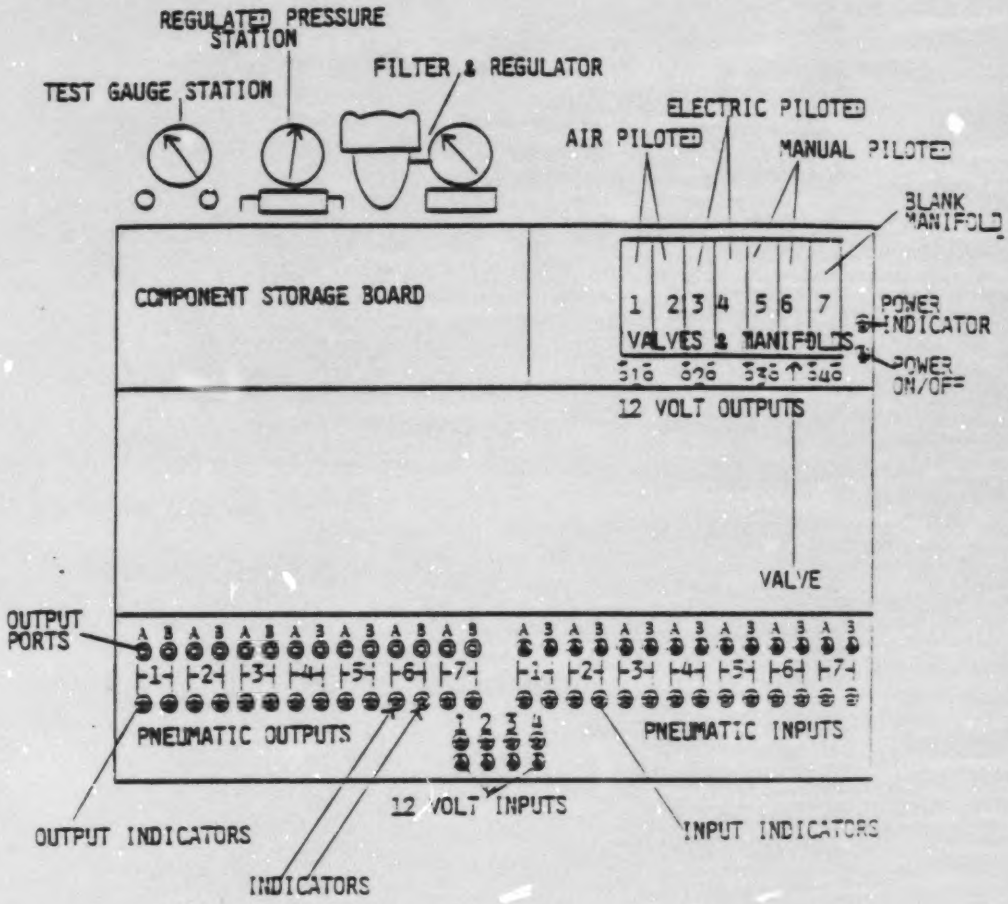


ILLUSTRATION #2

Program	Task	Page
[illegible]	[illegible]	5

CIRCUIT TESTING PROCEDURE

1 - The components for this activity are internally connected. ie the outputs from valve NO. 6 are connected to the output indicators NO. 6A & 6B.

2 - Move the lever operator of valve NO. 6 forward; then back again. How do the output indicators respond to actuation of the valve?

_____

_____

_____

OBSERVATION:

- What takes place as the valve is shifted manually?

_____

_____

- List three (3) reasons for using a manucily operated valve.

1. _____

2. _____

3. _____

INTERMEDIATE OBJECTIVE #2

Connect pneumatic piloted valves.

LEARNING STEPS (Activities)

1. Review Student Learning Guide cited in Resource #1 to recall piloted valve action.
2. Read Information Sheet cited in Resource #1 to learn about air operated valves.
3. Complete the circuit testing cited in Resource #2 to assure mastery of the circuit.
4. Proceed to the Intermediate Objective cited in Resource #3.

RESOURCES

1. Student Learning Guide #212 is available from your instructor.
2. Information Sheet #2 begins on page 10 and is entitled "Pneumatic Valve.
3. Procedure Sheet #2 begins on page 1 and is entitled "Pneumatic Valves."
4. Intermediate Objective #3 begins on page 11.

INFORMATION SHEET #2

- **SUBJECT:** PNEUMATIC VALVES
- **OBJECTIVE:** To operate a pneumatic piloted valve using pneumatic input signals
- **MATERIALS NEEDED:** 1 - 3RAT500 PNEUMATIC TRAINER
  1 - Two position pneumatically piloted valve
- **PROCEDURE:** Using the above listed components, set up the pneumatic circuit as shown in illustrations 1 & 2.

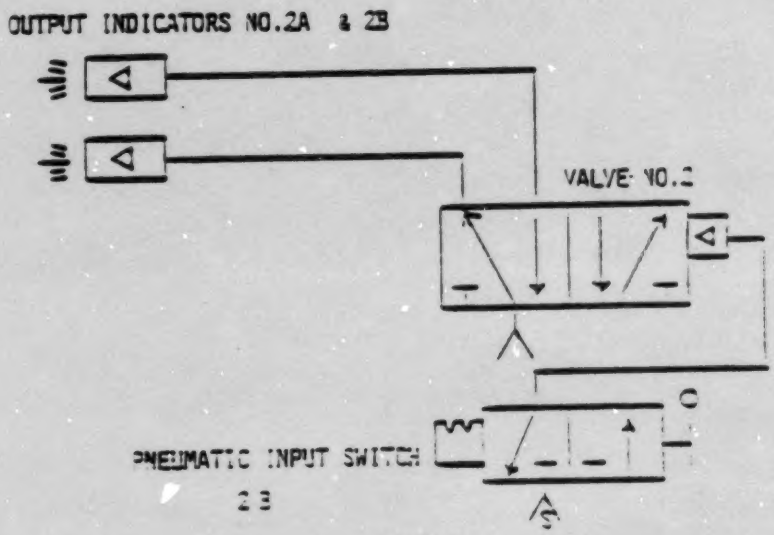


ILLUSTRATION #1

INFORMATION SHEET #2(Cont)

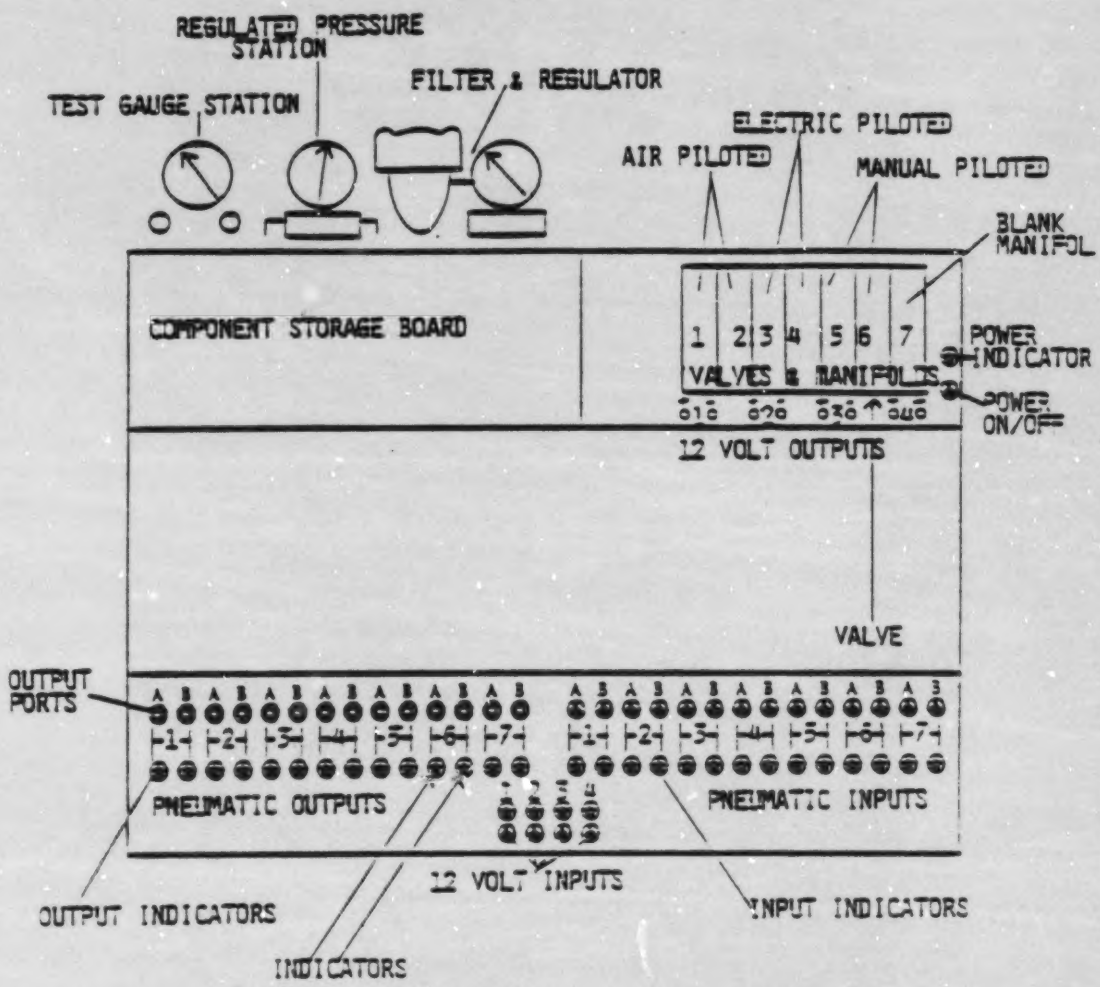

REGULATED PRESSURE STATION
TEST GAUGE STATION
FILTER & REGULATOR
ELECTRIC PILOTED
AIR PILOTED
MANUAL PILOTED
BLANK MANIFOL
COMPONENT STORAGE BOARD
1 2 3 4 5 6 7
VALVES & MANIFOLDS
POWER INDICATOR
POWER ON/OFF
12 VOLT OUTPUTS
VALVE
OUTPUT PORTS
A B A B A B A B A B A B A B A B A B A B A B A B A B A B
1 2 3 4 5 6 7 1 2 3 4 5 6 7
PNEUMATIC OUTPUTS
PNEUMATIC INPUTS
1 2 3 4
12 VOLT INPUTS
OUTPUT INDICATORS
INPUT INDICATORS
INDICATORS

ILLUSTRATION #2

Program	Task	Page
17.1002	213	3

PROCEDURE SHEET #2

CIRCUIT TESTING PROCEDURE

1 - The components for this activity are internally connected. ie the outputs from valve NO. 6 are connected to the output indicators NO. 6A & 6B.

2 - Move the lever operator of valve NO. 6 forward; then back again. How do the output indicators respond to actuation of the valve?

_____

_____

_____

OBSERVATION:

- What takes place as the valve is shifted manually?

_____

_____

- List three (3) reasons for using a manually operated valve.

1. _____

2. _____

3. _____

Program	Task	Page
17.1002	213	10

INTERMEDIATE OBJECTIVE #3

Connect electric piloted valves.

LEARNING STEPS (Activities)

1. Review Student Learning Guide cited in Reference #1.
2. Read Information Sheet cited in Resource #1 to learn about electric valves.
3. Complete the circuit testing cited in Resource #2 to assure mastery of the circuit.
4. Proceed to Intermediate Objective cited in Resource #3.

RESOURCES

1. Student Learning Guide #212 is available from your instructor.
2. Information Sheet #3 begins on page 12 and is entitled "Electric Valves
3. Procudure Sheet #3 begins on page 14 and is entitled "Electric Valves."
4. Intermediate Objective #4 begins on page 15.

Program	Task	Page
17.1002	213	11

INFORMATION SHEET 3

- **SUBJECT:** PNEUMATIC VALVES
- **OBJECTIVE:** To operate a pneumatic valve using electrical input signals
- **MATERIALS NEEDED:** 1 - BRAT500 PNEUMATIC TRAINER
  1 - Two position electrically operated (solenoid) valve 12VAC
- **PROCEDURE:** Using the above listed components, set up the pneumatic circuit as shown in illunstrations 1 & 2.

OUTPUT INDICATORS NO. 3A & 3B

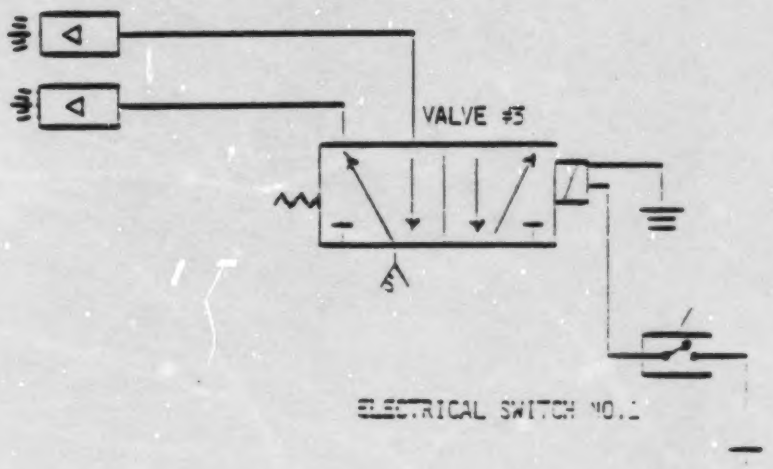


ILLUSTRATION #1

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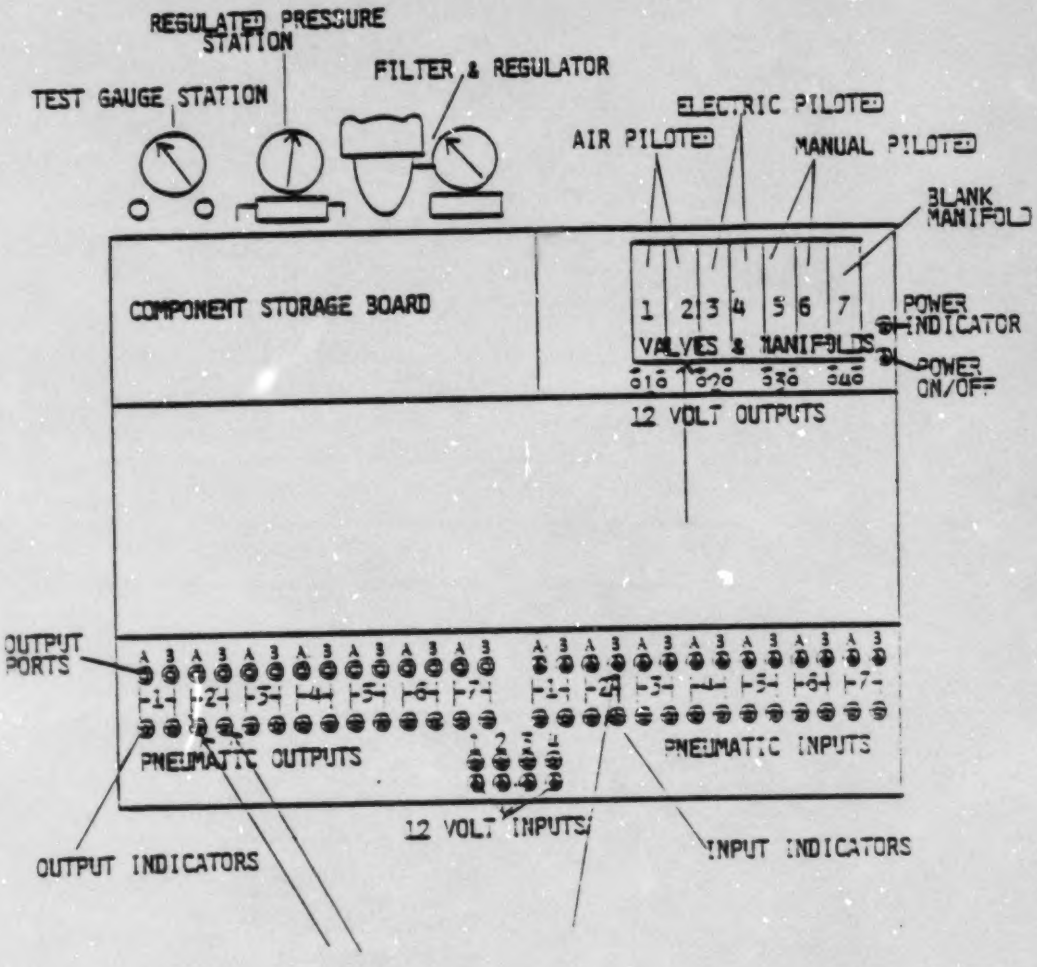


ILLUSTRATION #2

Program	Task	Page
17.1002	213	13

CIRCUIT TESTING PROCEDURE

✓ ☐ 1 - The components for this activity are internally connected; i.e. the pneumatic pilot switch 2B is connected to the pilot input of valve NO. 2. The outputs from valve NO. 2 are connected to output indicator NO. 2A & 2B.

☐ 1 - Move the lever on the pneumatic switch 2B back and forward. How does the indicator respond to actuation of the switch?

_____

_____

List four (4) reasons for a pneumatically piloted valve.

1. _____

2. _____

3. _____

4. _____

Which valve is considered the "SLAVE" valve?

_____

Which is the control valve?

_____

INTERMEDIATE OBJECTIVE

Connect quick exhaust valves

LEARNING STEPS (Activities)

1. Review Student Learning Guide cited in Resource #1.
2. Read Information Sheet cited in Resource #1 to learn about quick exhaust valves.
3. Complete the circuit testing cited in Resource #2 to assure mastery of the subject.
4. Complete the performance checklist for this terminal objective.

RESOURCES

1. Student Learning Guide 212 is Available from your instructor.
2. Information Sheet #4 begins on page 16 and is entitled "Quick Exhaust Valves".
3. Procedure #4 begins on page 17 and is entitles "Quick Exhaust Valves".
4. See your instructor.

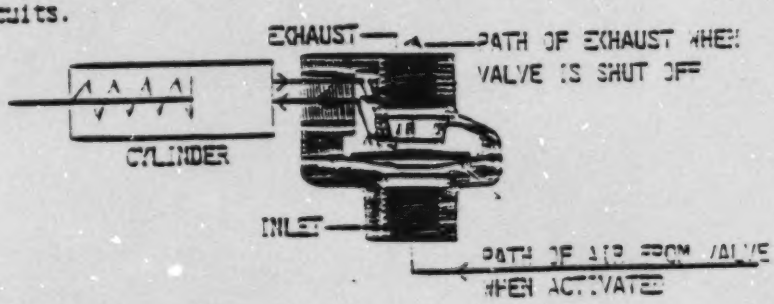
● SUBJECT: QUICK EXHAUST VALVES

● OBJECTIVE: To understand the operation and location of a quick exhaust valve within a pneumatic circuit.

● MATERIALS NEEDED:
1 - 3RAT500 PNEUMATIC TRAINER
1 - Quick exhaust valve
1 - Single acting, spring return cylinder
1 - 3 way manual valve (#5)
1 - Air line with fast disconnect
1 - Air line
1 - Pneumatic output (#5A)

Quick exhaust valves are used with air cylinders, rotary actuators, etc., to increase the speed of the component retraction by exhausting them directly into the atmosphere instead of through a long line back to the control valve. The quick exhaust of the air allows the use of smaller valves and connecting air lines.

A quick exhaust should be installed as close as possible to the cylinder ports. Industrial applications are for single acting, spring return, air cylinders. Quick exhausts are NOT used in hydraulic circuits.



When the valve control is actuated, air passes through the quick exhaust valve and extends the cylinder rod. When the valve is released, air passes out to the atmosphere allowing the cylinder rod to retract by spring force.

Program	Task	Page
17.1002	213	16

PROCEDURE: Using the listed components, set up the pneumatic circuit as shown in Illustrations #1 & #2.

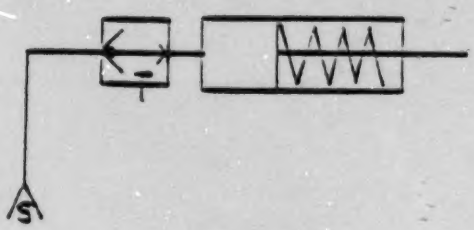


ILLUSTRATION #1

CIRCUIT TESTING PROCEDURE

1 - Attach an air line with a fast disconnect to output #5A, and the opposite end to the QUICK EXHAUST valve.

2 - Using a short air line, attach to the cylinder (Illustration #2).

3 - Activate valve #5 and hold to extend the cylinder rod.

4 - Release the valve and observe the cylinder rod retract and note the exhausted air coming from the quick exhaust valve.

5 - Re-assemble the same circuit, but this time DO NOT use the quick exhaust valve. Observe the rod speed. Repeat this activity until you observe the difference in rod speed.

INFORMATION SHEET

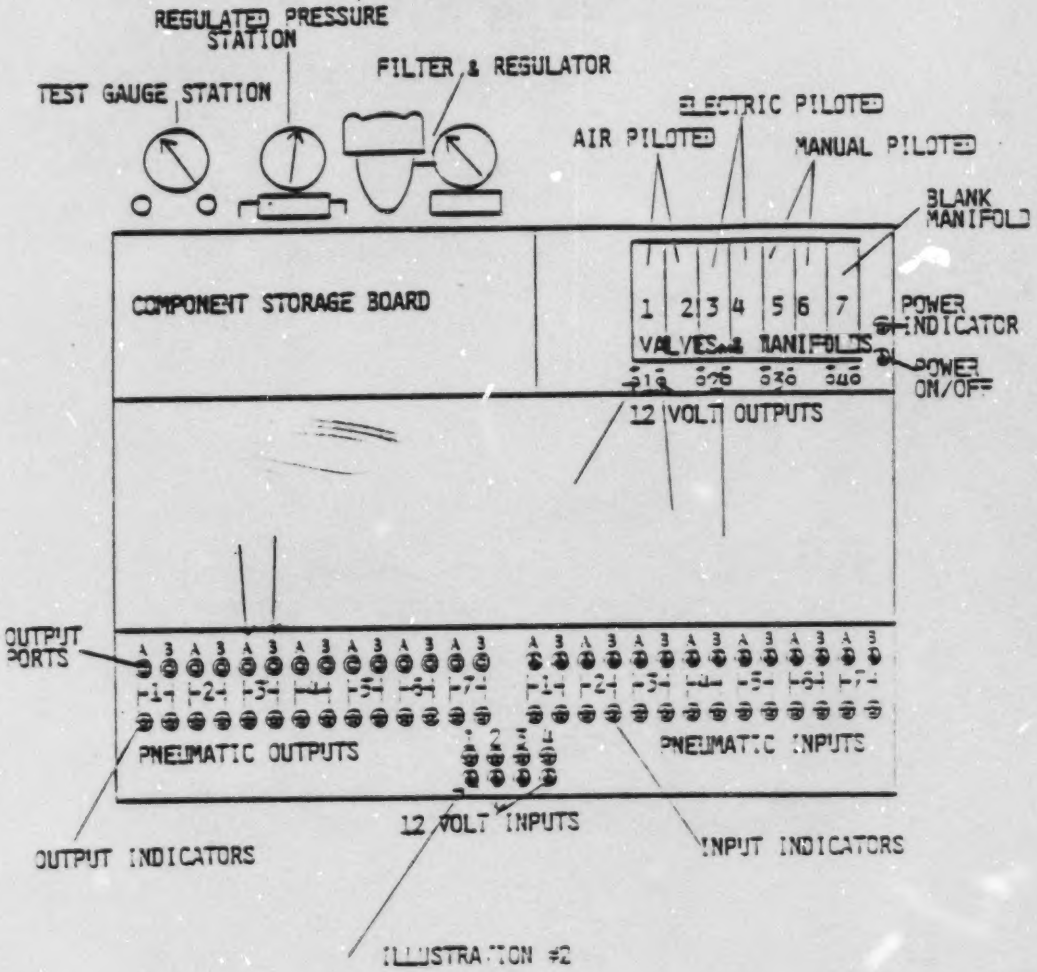


ILLUSTRATION #2

Program	Task	Page
[illegible]	[illegible]	[illegible]

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PERFORMANCE/PRODUCT CHECKLIST

Program: INDUSTRIAL ELECTRICAL MAINTENANCE

Task No: 211 DESCRIBE UNIFIED TECHNOLOGY CONCEPTS

Student's Name: _____ Date Of Attempt: _____

Evaluator's Name: _____ Evaluation Site: _____

Performance Attempt: 1 2 3 4

Terminal Performance Objective:

Given the material, design and needed tools you will connect pneumatic valves in a fluid system. You must score 100% on the performance/checklist for this objective.

Directions To The Student:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 10 minutes and must score at least _____ out of _____ points or 100 % for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

Directions To The Evaluator:

The student will contact you when ready for the evaluation. The student must complete the performance within 4 minutes and must score _____ out of _____ points or 100 % and all items marked with an asterisk (*) must be satisfactorily completed.

Program	Task	Page
17.1002	213	19

PERFORMANCE/PRODUCT CHECKLIST

The following tasks are to be completed using the equipment and material contained in the "Brat 501" pneumatic trainer.

1. Connect one manual valve to the gripper of the robotic arm.
2. Connect one electric piloted valve to the extender of the robotic arm.
3. Connect on pneumatic piloted valve to the riser of the robotic arm.
4. Connect a quick exhaust valve to a linear plunger on the BRAT 501 table.

CRITICAL ITEMS	ITEMS TO BE OBSERVED OR CHECKED	RATING YES	RATING NO
*	1. Selected correct manual valve.		
*	2. Connected manual valve to gripper.		
*	3. Selected correct electric piloted valve.		
*	4. Connected electric piloted valve to extender.		
*	5. Selected correct pneumatic piloted valve.		
*	6. Connected pneumatic piloted valve to the riser.		
*	7. Selected correct quick exhaust valve.		
*	8. Connected quick exhaust valve to linear plunger.		

TOTAL POINTS EARNED =

POINTS NEEDED FOR MASTERY = 8
TOTAL POINTS POSSIBLE = 8

LAKE COUNTY AREA VOCATIONAL CENTER

COMPETENCY-BASED INDIVIDUALIZED VOCATIONAL EDUCATION INSTRUCTION

STUDENT LEARNING GUIDE

Produced By M. H. WHITMER Date 5/85

TASK: CONNECT FLUID SYSTEM ACTUATORS

PURPOSE: You must understand how to connect fluid system actuators into a robotic or automated system circuit. The intermediate objectives under this task presents the method of connecting actuators to help you achieve the needed understnading. The modern electrical maintenance person knows how to connect actuators into the circuit for proper operation.

INDUSTRIAL ELECTRICAL MAINTENANCE

Program	Task	Est.Time	Prereq.
17.1002	214	2 hrs.	213

edk

LEARNING CONTRACT (optional)

1. STUDENT DATA

NAME _____ SOCIAL SECURITY NUMBER _____

LENGTH OF CONTRACT (NORMAL TIME IN HOURS) _____

2. TERMINAL PERFORMANCE OBJECTIVE

Given the material and tools along with a performace checklist, you will connect fluid system actuators as requested. You must score 100% on the performance checklist for this objective.

2a. INTERMEDIATE OBJECTIVE(s)

1. Connect double acting cylinders.
2. Connect spring action return cylinders.

3. AGREEMENT

I, _____ agree to complete the above stated terminal performance requirement within _____ to _____ I further recognize that the conditions of the contract (performance and time agreement) report my ability to perform the requirements of the occupation and record my progress.

_____ Student's Signature

_____ Instructor's Signature (verifies competency)

Program	Task	Page
17.1002	214	2

INTERMEDIATE OBJECTIVE #1

Connect double acting cylinders.

LEARNING STEPS (Activities)

1. Review the student Learning Guide cited in Resource #1 to recall air operated cylinder action.
2. Follow the procedure cited in Resource #2 to observe the action of a double acting cylinder.
3. Complete the testing procedure cited in Reference #3 to assure comprehension.
4. Follow the procedure cited in Resource #4 to learn how to stop a cylinder in mid stroke.
5. Complete the testing procedure cited in Reference 5 to assure subject comprehension.
6. Follow the procedure cited in Resource #6 to learn the actions of a three position valve and double acting cylinder.
7. Complete the circuit testing procedure cited in Resource 6 to learn the actions of a three position valve and double acting cylinder.
8. Follow the procedure cited in Resource 8 to learn the action of a blocked center 3 way valve and double acting cylinder.
9. Complete the circuit testing procedure cited in Resource 9.

RESOURCES

1. Student Learning Guide 212 is available from your instructor.
2. Procedure Sheet #1 begins on page 4
3. The procedure sheet #1 testing procedure begins on page 5.
4. Procedure sheet #2 begins on page 7.
5. The procedure sheet #2 testing procedure begins on page 8.
6. Procedure sheet #3 begins on page 10.
7. procedure sheet #3 circuit testing procedure begins on page 12.
8. Procedure sheet #4 begins on page 14.
9. Procedure sheet #4 circuit testing procedure begin on page #15.

INTERMEDIATE OBJECTIVE #1 con't

Conntect double acting cylinders. Con't

LEARNING STEPS (Activities)

10. Follow the procedure cited in resoure 10.

11. Complete the circuit testing procedure cited in resource 11.

12. Have your instructor initial your progress to the point.

13. Proceed to page 17.

RESOURCES

10. Procedure sheet #5 begins on page #16.

11. Procedure sheet #5 circuit testing begins on page 18.

12. Signed by instructor.

_____

PROCEDURE SHEET

SUBJECT: DOUBLE ACTING CYLINDERS

OBJECTIVE: To observe the action of a double action cylinder

MATERIALS NEEDED:
1 - BRAT500 PNEUMATIC TRAINER
1 - Double action cylinder
1 - Lever, spring return, 3 position valve
2 - Air line hoses with fast disconnects

PROCEDURE: Using the above listed components, set up pneumatic circuit as shown in illustrations 1. & 2.

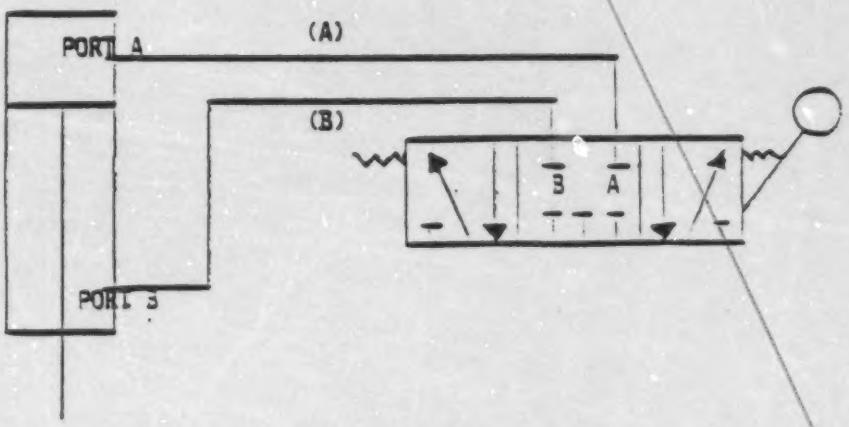

ILLUSTRATION # 1

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PROCEDURE SHEET

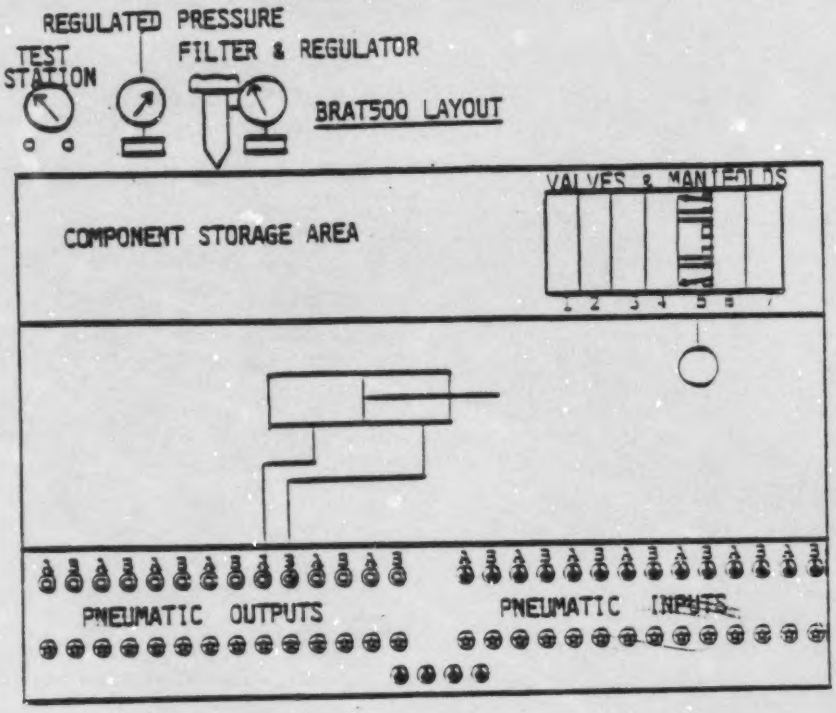

ILLUSTRATION # 2

CIRCUIT TESTING PROCEDURE

✓ = 1 - Check all connections as indicated in illustrations

= 2 - Move valve lever back. What is the reaction of the cylinder?

_____

_____

= 3 - Move the valve lever forward. What is the reaction of the cylinder?_____

_____

Program	Task	Page
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- 4 - Move the lever either forward or back and release it before the cylinder completes its stroke. What took place now?

_____

_____.

- 5 - Disconnect port A from the PNEUMATIC OUTPUT connection on the trainer and follow procedures # 2 & # 3. What took place now?_____

_____.

* CONCLUSION: A double acting cylinder must have air pressure applied to both ports A & B inorder to advance or retract.

PROCEDURE SHEET

- **SUBJECT:** DOUBLE ACTING CYLINDERS
- **OBJECTIVE:** Stopping a double acting cylinder in mid stroke without any stroke creep and control the speed in both directions - metered out
- **MATERIALS NEEDED:**
  1 - BRAT500 PNEUMATIC TRAINER
  1 - Double acting, single ended cylinder
  1 - Pneumatic piloted valve
  1 - Pressure regulator station
  2 - Flow controls
  Air lines and disconnects
- **PROCEDURE:** Using the above listed components, set up the pneumatic circuit as shown in illustrations 1 & 2.

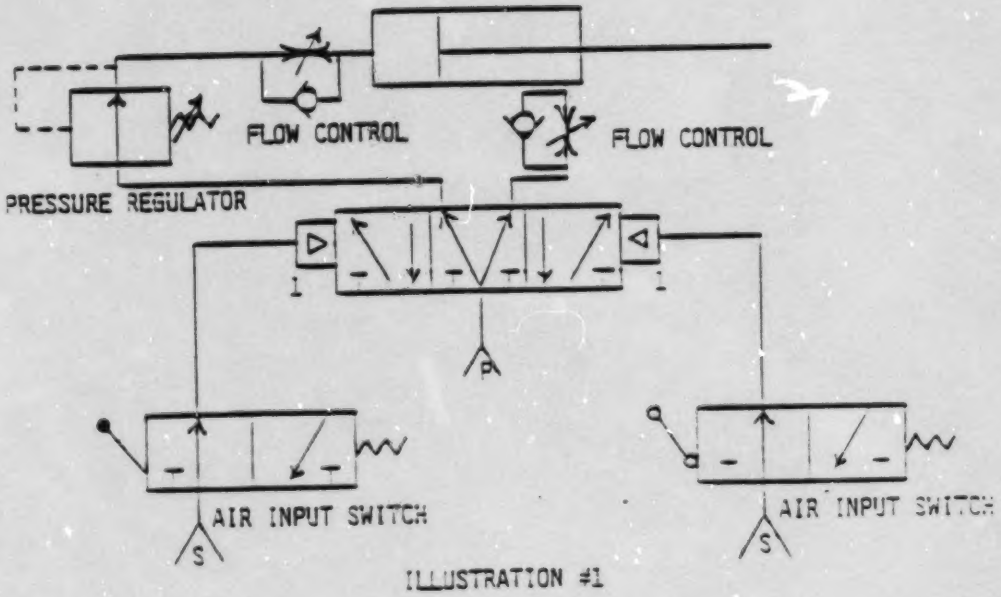

ILLUSTRATION #1

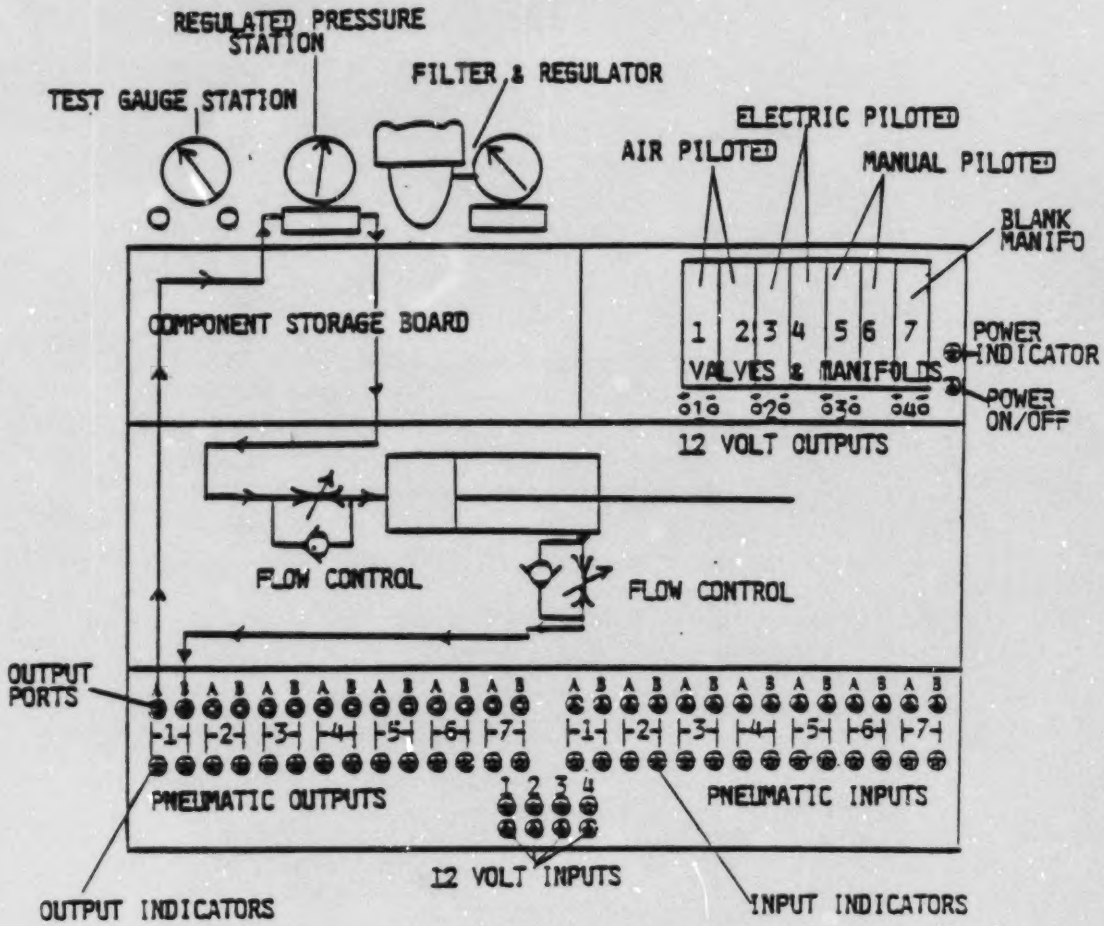

ILLUSTRATION #2

CIRCUIT TESTING PROCEDURE

= 1 - Check all connections as indicated in illustrations

= 2 - Adjust regulated pressure station to main supply for equal pressure.

= 3 - Close both flow controls and open 1/2 turn

= 4 - Operate the Pneumatic input 1A. What reaction just took place?

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☐ 5 - Close input 1A and open input 1B. What reaction took place?

_____.

☐ 6 - Repeat 4 & 5 adjusting the flow controls to get a slow motion back and forth.

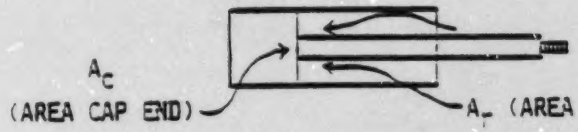
☐ 7 - Use input 1B to retract cylinder and actuate input 1A stopping the cylinder mid stroke.

☐ 8 - Repeat step 7 adjusting the regulated pressure station until the cylinder stops and holds its position.

CONCLUSION:

Because of unequal areas between the rod and the cap side of the piston, when equal pressure is supplied to both sides of the cylinder, the cylinder will advance due to less area on the rod side.
By decreasing the pressure on the opposite will equalize the force on the piston making it possible to stop the cylinder mid stroke. Using the following formula lets prove our theory!

PRESSURE x AREA = FORCE



$P_1 \times A_c = P_2 \times A_r$ (Cylinder rod in equilibrium)
To accomplish this a 3 position valve is required with pressure open to both cylinder ports. Calculate theoretical pressure on any regulator as follows;

A_c bore size of 1 1/8, area = 1.00 Sq. inches
A_r bore less 1/4" diameter rod = .75 Sq. inches

P_1 (LINE) x A_r
80 x .75 = 60
P_2 x 1.00 = 60
$P_2 = \frac{60}{1.00}$ = 60 PSI

How does this compare with actual pressure required to stop the cylinder using the regulated pressure station?

_____

_____

PROCEDURE SHEET

SUBJECT: DOUBLE ACTING CYLINDERS

OBJECTIVE: To advance and retract a double acting cylinder using a manually operated, 3 position 4 - way valve, spring centerd, with "A" & "B" ports open to exhaust in the center position

MATERIALS NEEDED:

1 - BRAT500 PNEUMATIC TRAINER
1 - Lever operated valve (#5)
1 - Double acting cylinder
2 - Air lines with fast disconnects

PROCEDURE: Using the above listed components, set up the pneumatic circuit as shown in illustration #1 and connect the components as shown in illustration #2

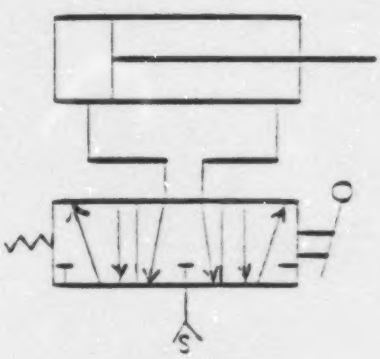


ILLUSTRATION #1

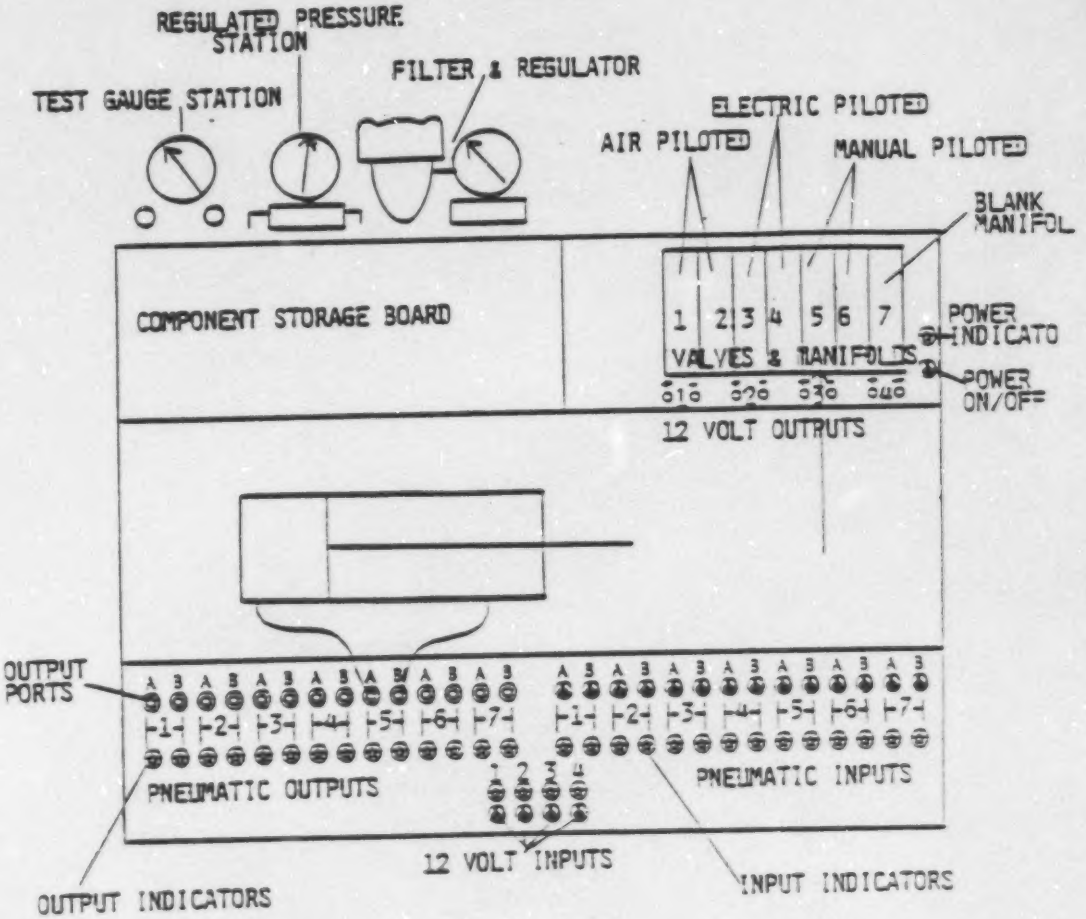


ILLUSTRATION #2

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CIRCUIT TESTING PROCEDURES

✓ ☐ 1 - Advance and retract the cylinder rod by moving the valve lever forward, then backward.

☐ 2 - Now release the valve lever and try to move the cylinder rod by hand. Does it move freely?_____

● CONCLUSION:

When the valve is in the center position, the cylinder ports are open to the exhaust allowing the cylinder rod to move freely. This type of an open center valve might prove to be useful in a circuit when it may be necessary to make adjustments without disconnecting the air supply.

● NOTE: Further information available in the "ROBOTIC APPLICATIONS FOR PNEUMATICS & HYDRAULICS" chapter 6 page 12.

PROCEDURE SHEET

SUBJECT: DOUBLE ACTING CYLINDERS

OBJECTIVE: To advance and retract a double acting, double rod cylinder using a pneumatically piloted 4 way, 3 position valve with "A" & "B" ports blocked in the center position.

MATERIALS NEEDED:
1 - BRAT500 PNEUMATIC TRAINER
1 - Pneumatically piloted valve #1
1 - Double acting, double rod cylinder
2 - Air lines with quick disconnects

PROCEDURE: Using the above listed components, set up the pneumatic circuit as shown in illustration #1 and connect the components as shown in illustration #2.

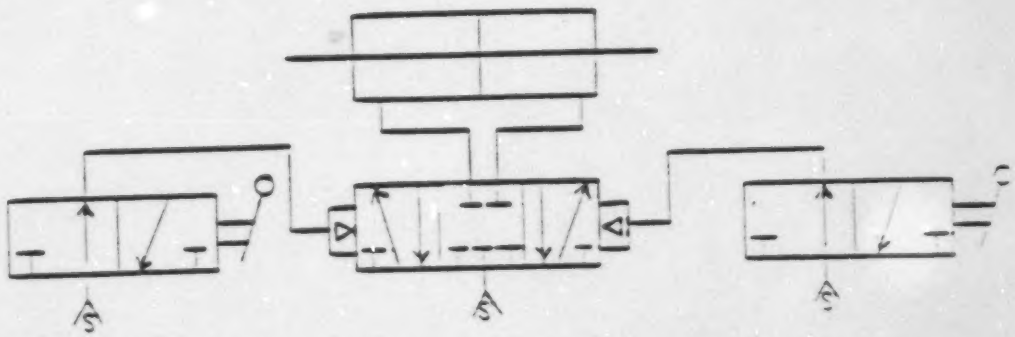

ILLUSTRATION #1

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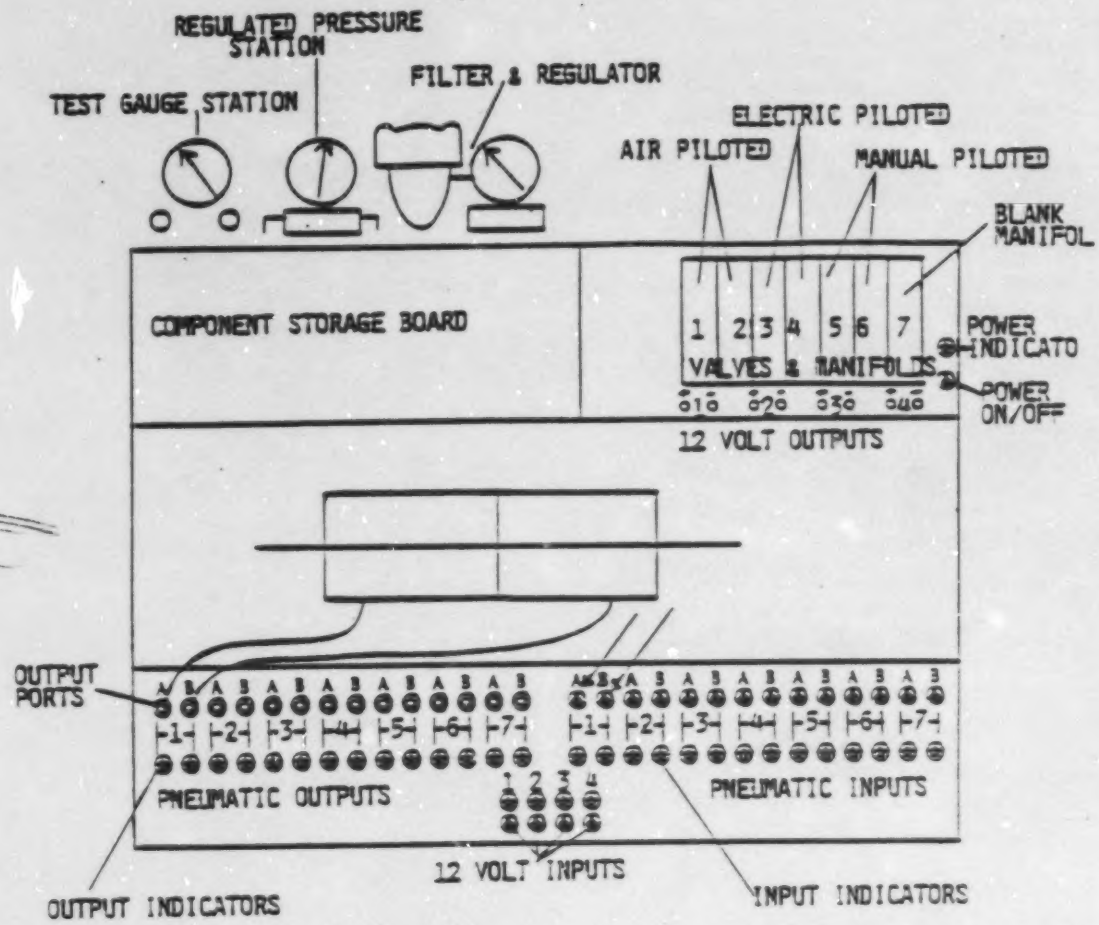

ILLUSTRATION #2

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CIRCUIT TESTING PROCEDURES

☐ 1 - Advance and retract the cylinder rod by alternately moving air input switch 1A on, then off. Repeat the same procedure using air input switch 1B.

☐ 2 - What happens when 1A is not returned to the off position and 1B is turned on?_____

_____.

● NOTE: Because the valve cannot shift without first exhausting the opposite pilot, the cylinder rod will remain in the same position!

☐ 3 - Advance the rod in either direction and return the air switch to the off position before the rod fully extends.

☐ 4 - Does the rod stay in this position?_____.

● NOTE: The pressurized air is trapped in the cylinder and since a double rod cylinder has equal piston area on each side, the forces are equal.

PROCEDURE SHEET

SUBJECT: DOUBLE ACTING CYLINDERS

OBJECTIVE: To advance and retract a double acting cylinder using an electrically piloted, 2 position, spring return 4 way valve.

MATERIALS NEEDED:

1 - BRAT500 PNEUMATIC TRAINER
1 - Electric solenoid operated valve (#4)
1 - Double acting cylinder
2 - Air lines with quick disconnects

PROCEDURE: Using the above listed components, set up the pneumatic circuit as shown in illustration #1 and connect the components as shown in illustration #2.

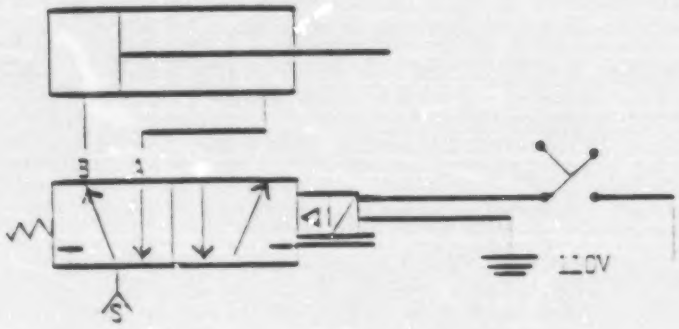

ILLUSTRATION #1

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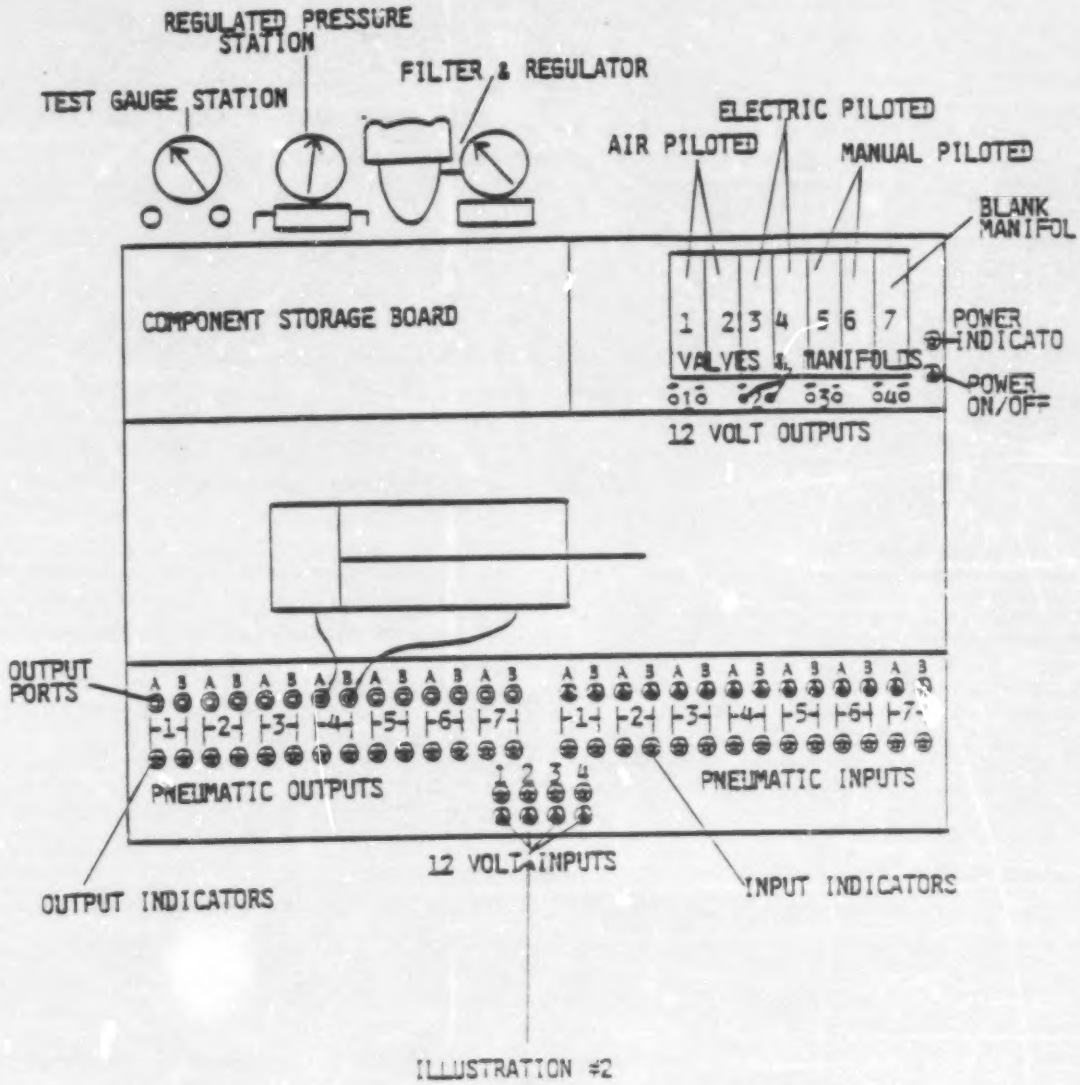

ILLUSTRATION #2

Program	Task	Page
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CIRCUIT TESTING PROCEDURES

✓ ☐ 1 - Advance and retract the cylinder rod by moving the electrical toggle switch #2.

☐ 2 - Why is only one switch required to move the cylinder rod in two directions?

_____

_____.

☐ 3 - If the switch is returned before the cylinder fully extends, how does the cylinder respond?

_____

_____.

☐ 4 - If a limit switch was used to actuate the valvr, what must be done to keep t[illegible] cylinder from retracting before it fully extends?

_____

_____.

INTERMEDIATE OBJECTIVE #2

Connect spring action return cylinders

LEARNING STEPS (Activities)

1. Review Learning Guide in Resource #1 to recall valve and cylinder actions.
2. Follow the procedure cited in Resource 2 to learn what spring return action is.
3. Complete the circuit testing procedure cited in resource 3.
4. Complete the procedure cited in resource 4.
5. Proceed to next student Learning Guide

RESOURCES

1. Student Learning Guide 21 is available from the instructor.
2. Procedure #1 begins on page 20.
3. procedure sheet #1 circuit testing procedure begins on page 22.
4. Obtain your Performance check list from your instructor.
5. Student Learning Guide 215 is available from your instructor.

PROCEDURE SHEET

SUBJECT: SPRING RETURN CYLINDERS

OBJECTIVE: To advance and retract a spring return cylinder using a manually operated, two (2) position, four (4) way valve without spring return

MATERIALS NEEDED:
1 - BRAT500 PNEUMATIC TRAINER
1 - Lever operated valve
1 - Single acting spring return cylinder
1 - Air line with quick disconnect

PROCEDURE: Using the above listed components, set up the pneumatic circuit as shown in Illustration #1 and connect the components as shown in Illustration #2.

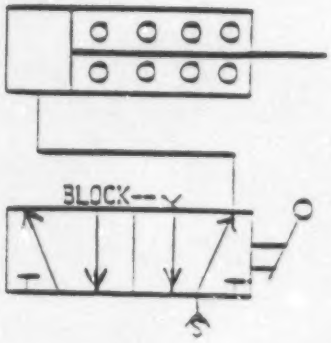

ILLUSTRATION #1

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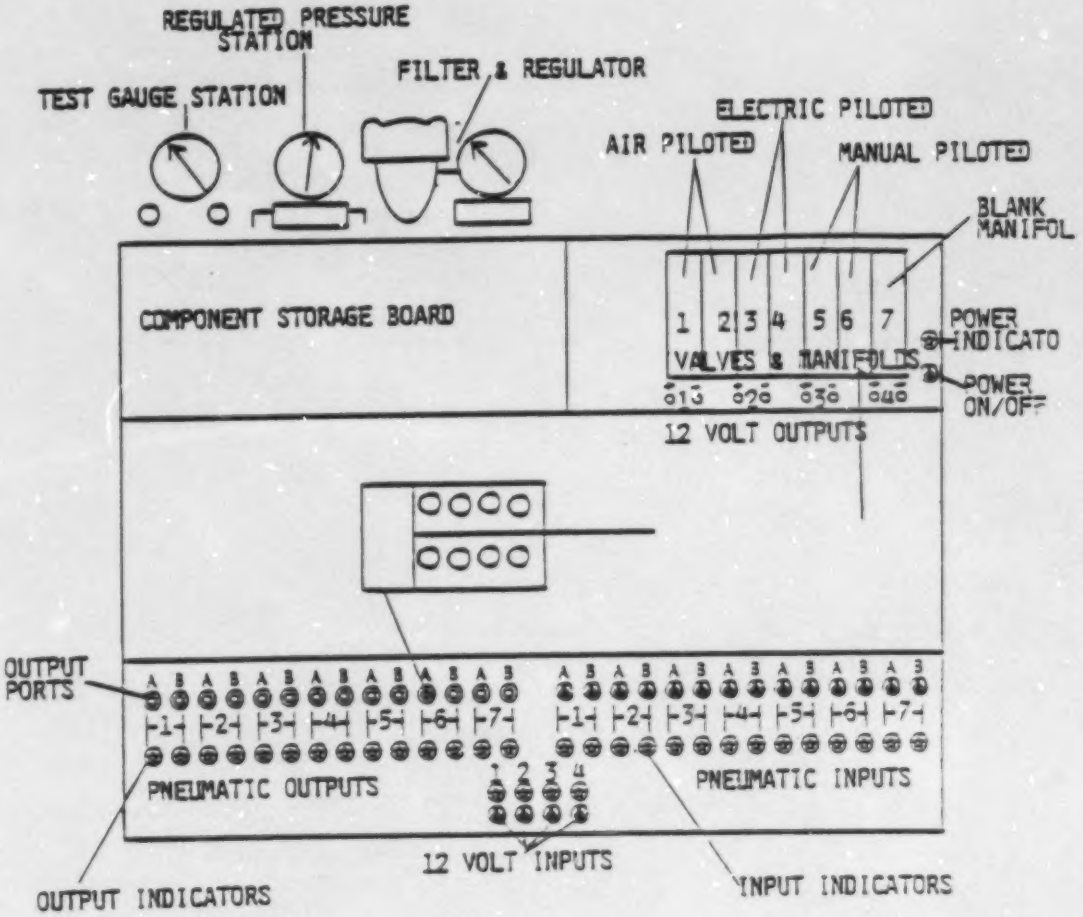

ILLUSTRATION #2

CIRCUIT TESTING PROCEDURE

✓ ☐ 1 - Advance the cylinder rod by moving the valve lever (#6) forward, then release the lever. Does the cylinder rod remain in the advanced position?_____.

WHY?_____.

☐ 2 - Retract the valve lever, what happens to the cylinder rod?

_____.

☐ 3 - What moved the cylinder rod back?

_____.

☐ 4 - The valve is a four (4) way, what happened to the output when the valve lever was retracted?

_____.

STUDENT NOTES

_____

_____

_____

_____

_____

_____

_____

_____

PERFORMANCE/PRODUCT CHECKLIST

Program: Industrial Electrical Maintenance

Task No: 214

Student's Name: _____ Date Of Attempt: _____

Evaluator's Name: _____ Evaluation Site: _____

Performance Attempt: 1 2 3 4

Terminal Performance Objective:

Given its material and tools along with a performance checklist, you will connect fluid system actuators as requested. You must score 100% on the performance checklist fo this object.

Directions To The Student:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 10 out of 10 points or 100 % for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

Directions To The Evaluator:

The student will contact you when ready for the evaluation. The student must complete the performance within 30 minutes and must score 10 out of 10 points or 100 % and all items marked with an asterisk (*) must be satisfactorily completed.

CRITICAL ITEMS	ITEMS TO BE OBSERVED OR CHECKED	RATING YES	RATING NO
	1. Read the procedure sheet before beginning		
	2. Selected the tools and materials needed		
	3. Selected the proper valve as specified in the procedure		
	4. Connected valves to cylinders correctly		
	5. Adjusted air pressure regulator before testing circuit		
	6. Followed procedure for circuit test		
	7. Recorded data obtained		
	8. Disconnected all components safely		
	9. Returned parts to tool crib		
	10. Cleaned up work area		

TOTAL POINTS EARNED =

POINTS NEEDED FOR MASTERY = 100
TOTAL POINTS POSSIBLE = 100

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COMPETENCY-BASED INDIVIDUALIZED VOCATIONAL EDUCATION INSTRUCTION

STUDENT LEARNING GUIDE

Produced By M.H. WHITMER Date 5/85

TASK: CONNECT VENTURI VACUUM GENERATOR

PURPOSE: You must understand how to connect the venturi vacuum generator into a fluid system circuit. The intermediate objectives under this task presents the method of connecting venturi vacuum generators to help you achieve the needed understanding. The modern electrical maintenance person knows how to connect venturi vacuum generators into the circuit for proper operation.

INDUSTRIAL ELECTRICAL MAINTENANCE

Program	Task	Est.Time	Prereq.
17.1002	215	2 hrs	214

edk

LEARNING CONTRACT (optional)

1. STUDENT DATA

NAME _____ SOCIAL SECURITY NUMBER _____

LENGTH OF CONTRACT (NORMAL TIME IN HOURS) _____

2. TERMINAL PERFORMANCE OBJECTIVE

Given the needed material and tools along with a performance checklist, you will connect the venturi vacuum generator. You must score 100% on the performance checklist for this objective.

2a. INTERMEDIATE OBJECTIVE(s)

1. Identify the physical parts of the venturi tube.
2. Connect the venturi vacuum generator.

3. AGREEMENT

I, _____ agree to complete the above stated terminal performance requirement within _____ to _____. I further recognize that the conditions of the contract (performance and time agreement) report my ability to perform the requirements of the occupation and record my progress.

_____ Student's Signature

_____ Instructor's Signature (verifies competency)

Program	Task	Page
17.1002	215	2

INTERMEDIATE OBJECTIVE #1

Identify the physical parts of the venturi tube.

LEARNING STEPS (Activities)

1. Read the material in the information sheet cited in Resource #1 to learn about the venturi tube.
2. Complete the self help in Resource #2 to assure subject comprehension.
3. Proceed to the next intermediate objective.

RESOURCES

1. Information Sheet #1 begins on page 4.
2. Drawing #AA is located on page 5.
3. Intermediate Objective #2 begins on page 6.

VELOCITY - PRESSURE RELATIONSHIP

Bernoulli's Law states that the higher the speed of a flowing fluid, the lower the pressure. As the speed decreases, the pressure increases, and, conversely as the speed increases, the pressure decreases. This law has numerous applications in the field of pneumatics and aeronautics. We also know that as we reduce the size of an opening the velocity increases while the pressure decreases. Devices such as pneumatic line lubricators, paint sprayers and carburetors operate on this principle.

Venturi:

The venturi-tube can be utilized to generate pressure differences in pneumatics. This device can cause a drop in pressure as a fluid flows through it. Essentially a venturi-tube is a short straight pipe section, or throat, between two tapered sections. Local pressure varies in the vicinity of the constriction. Thus, by attaching at the throat a manometer, the drop in pressure can be measured and the flow rate calculated. It is because of this characteristic that venturi devices are commonly used as air flow meters. In fact, they are more efficient than the sharp edged orifice because of its gradual smooth restriction.

The principal advantage of the venturi tube is that not more than 10-20 percent of the difference in pressure between the inlet and the throat is permanently lost due to friction. This is accomplished by the discharge cone of the restriction which gradually decelerates the flow with minimum turbulence. The transition from the reduced area to the enlarged downstream section is also gradual and the pressure will increase to practically its original pressure on the other end of the tube.

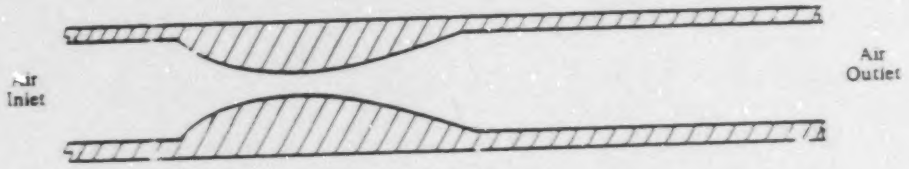
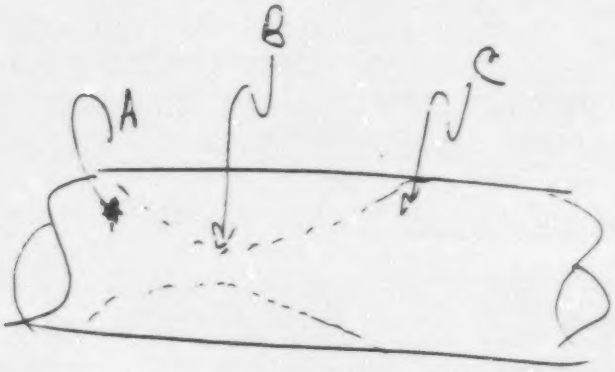


Figure A Typical Venturi – Cross Sectional View

INFORMATION SHEET #2

SELF - HELP

Identify the pressure and fluid behavior at each of the three areas, A, B, C.



A. _____

B. _____

C. _____

INTERMEDIATE OBJECTIVE #2

2. Connect the venturi vacuum generator.

LEARNING STEPS (Activities)

1. Follow the procedures cited in Resource #1 to connect a venturi vacuum.
2. Perform the circuit testing procedure cited in Resource #2.
3. Perform the evaluation project cited in Resource #3.
4. Continue to learning guide cited in Resource #4.

RESOURCES

1. Procedure Sheet #1 begins on page 7.
2. The procedure sheet #1 circuit testing procedure begins on page 8.
3. The performance checklist for this terminal performance objective begins on page 10.
4. See instructor for Student Learning Guide #216.

INFORMATION SHEET #2

SUBJECT: VENTURI VACUUM GENERATOR

OBJECTIVE: To pick up and release paper material using a venturi type vacuum generator operated by a manual, 2 position, 4 way pneumatic valve.

MATERIALS NEEDED:
1 - BRAT500 PNEUMATIC TRAINER
1 - Lever operated, 2 position, 4 way valve (#6)
1 - In-line flow control valve
1 - Air line with quick disconnect
1 - Air line

PROCEDURE: Using the above components, set up the pneumatic circuit as shown in illustration #1 and connect the components as shown in illustration #2.

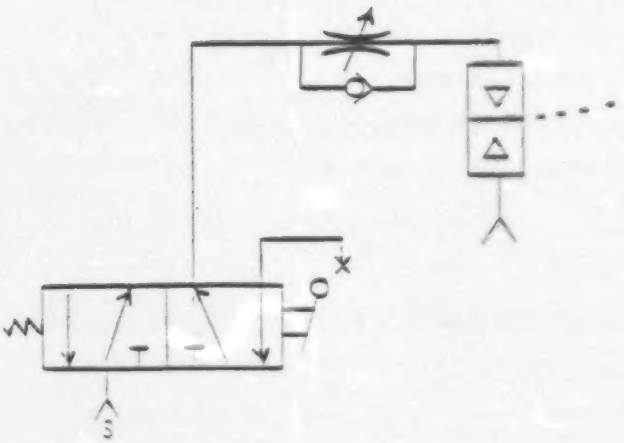


ILLUSTRATION #1

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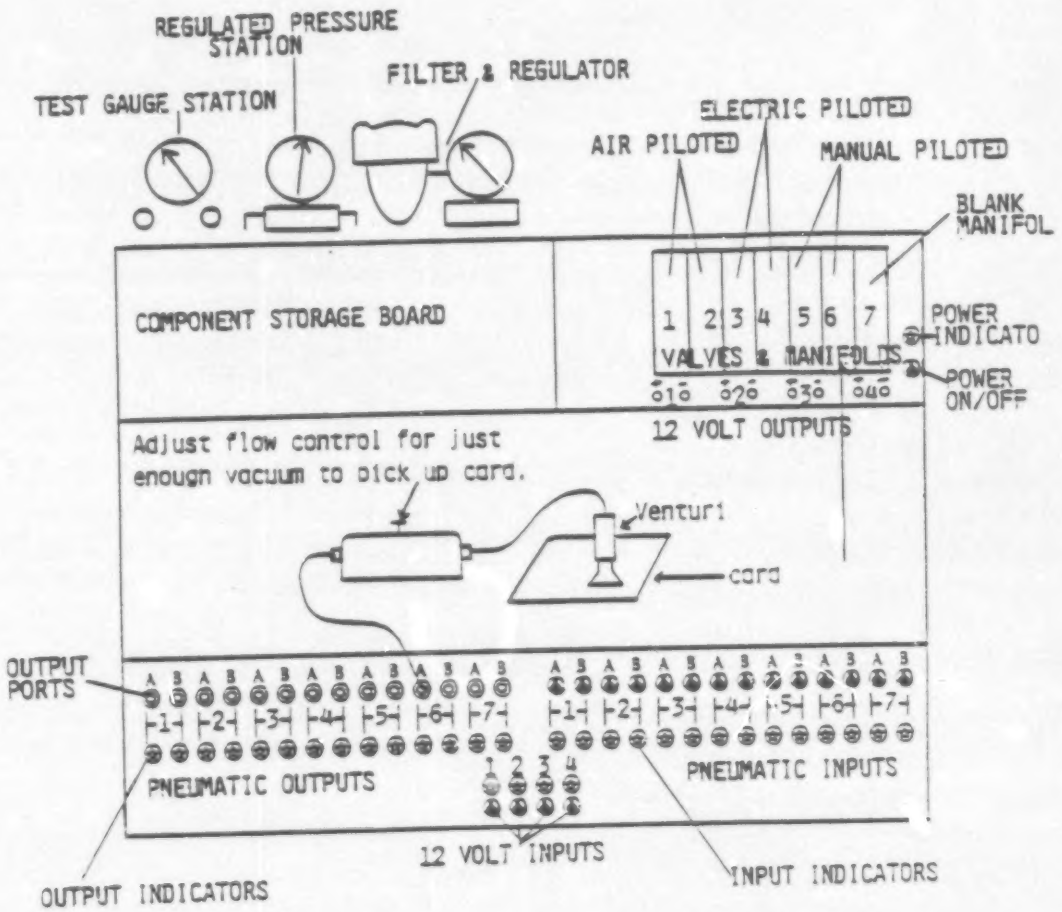

ILLUSTRATION #2

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• THE VENTURI TUBE •

The venturi-tube can be used to cause pressure differences in pneumatic circuits. The venturi-tube can cause a drop in pressure as a fluid flows through it. The standard venturi is a short straight pipe section between two tapered sections as seen below in illustration #3.

BERNOULLI'S LAW states that the higher the speed of a flowing liquid, the lower the pressure. As the speed decreases, the pressure increases, and as the speed increases, the pressure decreases.

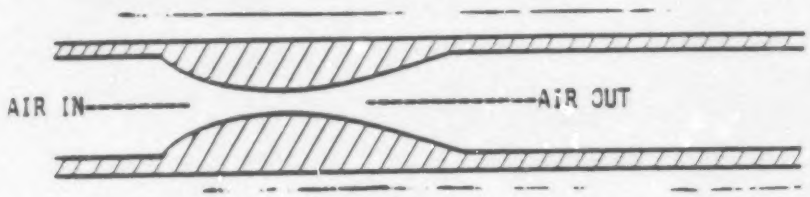

ILLUSTRATION #3

CIRCUIT TESTING PROCEDURES

✓ = 1 - Valve #6 is a 4 way valve, providing an output at "A" & "B" depending on which position the lever is positioned in. During this activity we are only using one output, 6A.

= 2 - Hold the venturi over a piece of paper or card and adjust the flow control valve until the paper or card is drawn against the suction cup on the end of the venturi.

= 3 - Repeat procedure #2, but try to pick up a paper or card adjusting the pressure gauge on the air supply station at various levels, decreasing the pressure each time. Note that the venturi still reacts very positive even at low pressures. At what pressure did the venturi stop operating?

_____

= 4 - We are putting pressure into the venturi, why does this result in a vacuum?_____

_____

Program	Task	Page
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PERFORMANCE/PRODUCT CHECKLIST

Program: INDUSTRIAL ELECTRICAL MAINTENANCE

Task No: 215

Student's Name: _____ Date Of Attempt: _____

Evaluator's Name: _____ Evaluation Site: _____

Performance Attempt: 1 2 3 4

Terminal Performance Objective:

Given the needed materials and tools along with a performance checklist, you will connect the venturi vacuum generator. You must score 100% on the performance checklist for this objective.

Directions To The Student:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 5 out of 5 points or 100 % for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

Directions To The Evaluator:

The student will contact you when ready for the evaluation. The student must complete the performance within 30 minutes and must score 5 out of 5 points or 100 % and all items marked with an asterisk (*) must be satisfactorily completed.

CRITICAL ITEMS	ITEMS TO BE OBSERVED OR CHECKED	RATING YES	RATING NO
	NOTE: Student will assemble and operate a fluid system to create a vacuum with a venturi tube using 40psi supply pressure		
	1. Read the complete procedure before starting to assemble		
	2. Selected the right parts and materials for system		
	3. Adjusted pressure regulator		
	4. Connected the components correctly		
	5. Tested venturi vacuum generator for amount of lift		

TOTAL POINTS EARNED =

POINTS NEEDED FOR MASTERY = 5
TOTAL POINTS POSSIBLE = 5

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STUDENT LEARNING GUIDE

Produced By M.H. WHITMER Date 5/85

TASK: DESCRIBE PRESSURE AND FORCE IN A FLUID SYSTEM

PURPOSE: You must understand the principles of pressure and force as they apply to robotics and automated manufacturing. The intermediate objectives under this task present the inter actions of pressure and force in the fluid system to help you achieve the needed understanding. The modern electrical maintenance person knows how pressure and force react in the fluid system to provide the energy for movement.

INDUSTRIAL ELECTRICAL MAINTENANCE

Program	Task	Est.Time	Prereq.
17.1002	216	2 hrs	215

edk

LEARNING CONTRACT (optional)

1. STUDENT DATA

NAME _____ SOCIAL SECURITY NUMBER _____

LENGTH OF CONTRACT (NORMAL TIME IN HOURS) _____

2. TERMINAL PERFORMANCE OBJECTIVE

Given a written evaluation, you will describe pressure and force as they apply to a fluid system . You must score 100% on the written test for this objective.

2a. INTERMEDIATE OBJECTIVE(s)

1. Describe the use of force in the fluid system.
2. Connect test system to measure force and pressure relationships.

3. AGREEMENT

I, _____ agree to complete the above stated terminal performance requirement within _____ to _____. I further recognize that the conditions of the contract (performance and time agreement) report my ability to perform the requirements of the occupation and record my progress.

Student's Signature _____

Instructor's Signature (verifies competency) _____

Program	Task	Page
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INTERMEDIATE OBJECTIVE #1

Describe the use of force in the fluid system.

LEARNING STEPS (Activities)

1. Read the information sheet cited in Resource #1 to learn about forces and pressures.

2. Complete the self-check quiz cited in Resource #2.

3. Proceed to next Intermediate Objective.

RESOURCES

1. Information Sheet #1 begins on page 4.

2. Information Sheet #1 Slef Check Quiz begins on page 13.

3. The second Intermediate Objective begins on page 15.

FLUID SYSTEMS AND PRESSURES

WHAT IS A FLUID SYSTEM?
WHAT IS PRESSURE? WHAT CAUSES PRESSURE?
HOW ARE PRESSURES MEASURED?
HOW DOES PRESSURE ACT LIKE A "FORCE" IN A FLUID SYSTEM?

Fluid systems are common in the world of technology. In general, fluid systems involve various fluids, pipes or hoses to carry the fluids, pressure devices like water pumps, and instruments here and there to measure the fluid flow rate and pressure differences. A fluid system that uses liquids is called a **hydraulic system.** A fluid system that uses gases is called a **pneumatic system.**

The fluid system we referred to earlier--water pumps, connecting hoses, engine block, radiator and water--is found in every automobile. The city water system, made up of an elevated water tank, underground pipes, water meters, house plumbing and faucets, is common in many parts of our country. Pneumatic systems involve pressurized gases in tubes, cleverly arranged to move and control key mechanical parts.

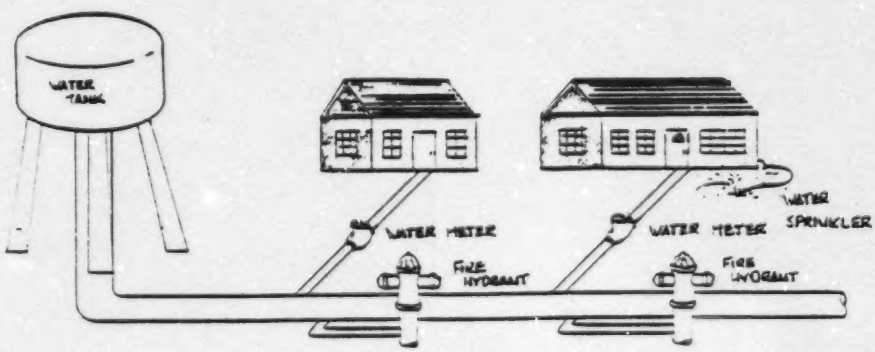


Fig. 1-20 A city water system depends on pressure to move water.

PRESSURES ACT LIKE FORCES

Whatever fluid system we examine, we find that all have several things in common. First, each system contains a fluid, either a liquid or a gas that moves through the system of connecting pipes and devices. Second, a pressure difference is generated in the system to move the fluid in a given direction and perform some special function, like opening or closing a valve. In this sense, pressure acts like a force in moving fluid through the system--in much the same way that a mechanical force (a push) moves a box, or a rotational force (a torque) tightens a bolt.

PRESSURE IS A FORCE PER UNIT AREA

Pressure is familiar to most of us. We all recognize the need for air pressure in tires. We watch lawn sprinklers barely throw out water when the water pressure is low. We hear the local weather forecaster talk about a high-pressure system moving in. It is a difference in pressure, between separated points in a fluid system, that causes fluids to move along the system--from points of high pressure to points of low pressure.

Pressure is defined as the force per unit area exerted by a fluid--liquid or gas. In the form of an equation, pressure is defined as:

$$P = \frac{F}{A}$$

where: F = force in newtons (N) or pounds (lb)
A = area in square meters (m^2) or square inches (in^2)
P = pressure in N/m^2 or lb/in^2

ATMOSPHERIC PRESSURE

One pressure that affects our daily lives is atmospheric pressure. Here on earth, we live at the bottom of a thick blanket of air. At sea level, the atmosphere presses down on us and everything else with a force of 14.7 pounds for every square inch of surface. At higher altitudes--like Pike's Peak--the

pressure is a little less. This "ocean" of gases--the atmosphere--is a blanket of air that extends up over us to a height of some 120,000 meters (about 75 miles). We call the force per unit area of 14.7 lb/in^2 (or 1.013×10^5 N/m^2) the **atmospheric pressure**. It acts equally in all directions and pushes with a force of 14.7 pounds on every square inch of surface--upwards, downwards, or sideways. Since pressure acts in all directions at any point in a fluid--unlike a force that acts in specific directions--it is a scalar. Thus pressure is completely described by specifying a magnitude--no direction is required.

ABSOLUTE AND GAGE PRESSURE

When working with fluid systems, pressure measurements are often reported as **absolute pressure** or **gage pressure**. It's important to know the difference. Let's think about filling a tire with air. We use a pump which forces more and more air (molecules of oxygen, nitrogen, helium, argon, etc.) into the tire. The tire fills up and takes on a rigid shape. If we check the air pressure with a tire gage, it might read 30 lb/in^2. What does that reading mean? Is it 30 lb/in^2 gage pressure or 30 lb/in^2 absolute pressure?

Let's try to reason it out. **Absolute pressure** is the total pressure measured above a reference of zero pressure--a perfect vacuum. **Gage pressure**, on the other hand is the pressure measured above atmospheric pressure. It is the total pressure minus atmospheric pressure. It is generally measured by a gage, hence the name "gage pressure."

GAGE PRESSURE = TOTAL PRESSURE - ATMOSPHERIC PRESSURE

So the tire gage reading of 30 lb/in^2 is a **gage pressure**! It means that the total pressure is really 30 lb/in^2 + 14.7 lb/in^2 or 44.7 lb/in^2. Inside the tire then, whether against the walls or treads, the trapped air pushes outwards on each square inch of tire surface with a force of 44.7 lb. But on the outside of the tire, the atmosphere pushes inward on each square inch of tire surface with a force of 14.7 lb. There is, then, a net outward push on

each square inch of tire surface of 30 lb/in^2. The tire gage measures this and records an air pressure of 30 lb/in^2.

Let's solve the following example dealing with total force pushing outward on an airplane window while the plane is at level flight high above the earth's surface. At this altitude, the pressure of the atmosphere would be considerably less than 14.7 lb/in^2. Why?

EXAMPLE 1-G: FORCE ON AN AIRPLANE WINDOW.

Given: An airplane window with surface area of 2 square feet. Air pressure inside the cabin is 8 pounds per square inch greater than the air pressure outside the window. Assume that cabin is pressurized so that air pressure is maintained at 14.7 lb/in^2--same as atmospheric pressure at sea level.

Find: (a) The net force on the window.
(b) Air pressure outside the plane.

Solution: (a) $P = \frac{F}{A}$

$F = PA$

$F = \left(8 \frac{lb}{in^2} \right)(288\ in^2)$ $\qquad 1\ ft^2 = 144\ in^2$

Force = 2304 lb pushing outward on the window.
The window must withstand a net force of 2304 lb.

(b) $P_{outside} = 14.7\ lb/in^2 - 8\ lb/in^2 = 6.7\ lb/in^2$
The pressure outside is less because the plane is at a high altitude--and only part of the 75 mile thick blanket of air (the atmosphere) now exists above the plane.

PRESSURE INCREASES WITH DEPTH

In a water tank, swimming pool, or a lake, the pressure in the water increases with depth. That's not too surprising! Let's think about a water tank. The deeper the tank, the more water there is on top of each square inch of the tank bottom. This means more pounds per square inch on the bottom--or higher pressure.

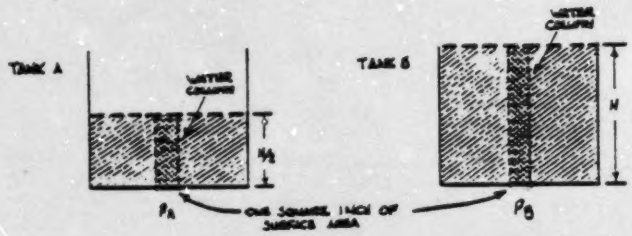


Fig. 1-21 Force per unit area on bottom of tank depends on height of water column above.

Consider two identical tanks, A and B. Tank A is half full of water, Tank B is full. Think about a square inch of surface at the bottom of Tank A and of Tank B. The column of water "sitting" on a square inch in Tank B is twice as high as that sitting on a square inch in Tank A. The column of water in B must have twice as much weight as the column in A. Since pressure is force per unit area (and weight is a force), it is clear that pressure P_B at the bottom of Tank B should be twice the pressure P_A at the bottom of Tank A. Suppose that Tank B were half as wide as Tank A, but depth of water remained H in Tank B and H/2 in Tank A, just as shown in Figure 1-21. Would P_B still be twice P_A?

We can put this all in a simple equation which tells us just how pressure in a liquid (or gas) increases with depth. The equation is:

$$P = \rho g h$$

where: ρ = mass density (like kg/m^3). (Here ρ is the Greek letter "rho")
g = acceleration due to gravity ($9.8\ m/s^2$)
h = liquid height (m)
P = pressure in N/m^2

In the English system of units, we usually talk about weight density (lb/ft^3) or just "density." Since we don't use mass density ($slugs/ft^3$), we can re-write the equation as:

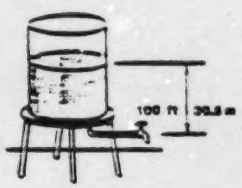
$$P = \rho_w h$$

where: ρ_w = weight density in lb/ft^3
h = liquid height in ft
P = pressure in lb/ft^2

Let's calculate the water pressure using both systems of units. Consider the following example.

EXAMPLE 1-H: WATER PRESSURE CALCULATION.

Given: The height of the water in a water system is 100 ft (30.5 m) above a faucet. The mass density of water (metric units) is 1000 kg/m^3. The weight density of water (English units) is 62.4 lb/ft^3.



Find: The pressure at the faucet in metric and English units.

Solution: (a) In metric units: $P = \rho g h$

$= (1000\ kg/m^3)(9.8\ m/s^2)(30.5\ m)$

$P = 298{,}900\ kg/m \cdot s^2$

But a $kg/m \cdot s^2$ is the same as N/m^2 (see note below)

$P = 298{,}900\ N/m^2$, in units of pressure.

Note: $\frac{N}{m^2} = \frac{\left(\frac{kg \cdot m}{s^2}\right)}{m^2} = \frac{kg}{m \cdot s^2}$ (refer to Table 1 for help)

(b) English Units: $P = \rho_w h$

$= (62.4\ lb/ft^3)(100\ ft)$

$= 6240\ lb/ft^2$

$= (6240\ lb/ft^2)(\frac{1\ ft^2}{144\ in^2})$

$P = 43.3\ lb/in^2$

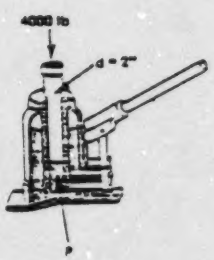
The units have been converted to the more familiar pounds per square inch. This is also force per unit area.

HYDRAULIC JACK

Pressure in an enclosed fluid pushes against all surfaces that trap the fluid. The hydraulic jack is a useful device that involves fluids to create a large lifting force on a flat surface. The automobile lift in most garages is an example of a hydraulic piston--or hydraulic jack--in action. The following example shows how pressure in a fluid, caused by pressing down on a handle to squeeze the fluid, is transmitted to a large surface area and developed into a large lifting force at that surface.

EXAMPLE 1-I: FLUID PRESSURE IN A HYDRAULIC JACK.

Given: A hydraulic jack is rated at 4000 lb lifting capacity and has a large piston with a diameter of 2 inches.



Find: Fluid pressure in the jack at maximum load.

Solution: Area: $A = \pi r^2$

$= (3.14)(1\ in)^2$

$A = 3.14\ in^2$

$P = \frac{F}{A}$

$= (4000\ lb) \div (3.14\ in^2)$

$P = 1274\ lb/in^2$

Thus, the fluid pressure throughout the inside of the jack, wherever fluid is found, is $1274\ lb/in^2$.

EQUILIBRIUM IN FLUID SYSTEMS

Motion occurs in a fluid system because pressure differences exist between different points in the system. It is for this reason that it's useful to think of pressure acting like a force in fluid systems. Let's make this point a little clearer. Figure 1-22 shows two tanks connected by a pipe containing an on-off valve. The pressure at the bottom of each tank is different because the water level in Tank 2 is higher than in Tank 1. The pressure P_1, at the bottom of Tank 1 is less than P_2, the pressure at the bottom of Tank 2. Now if the pipe between the two tanks is connected to each tank at the bottom, then the pressure on the left side of the valve is P_1 and that on the right side is P_2. Therefore, there must be a pressure difference across the valve. What happens if the valve is opened?

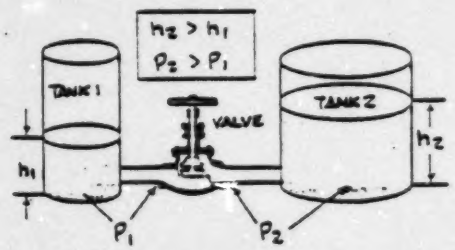


Fig. 1-22 Unbalanced pressures across valve.

Since pressure P_2 is greater than P_1, there will be a force per unit area on the right side of the valve greater than the force per unit area on the left side of the valve. Water will then flow through the valve from Tank 2 to Tank 1 until the levels in the two tanks are equal. When water depths in Tank 1 and Tank 2 are equal, P_1 and P_2 will be equal, and the system will be in equilibrium. This situation is shown in Figure 1-23.

Note that Tank 2 is larger and has more water than Tank 1. But pressure depends only on the depth. It does not depend on the shape of the container or the amount of water it holds. And since the depths are equal, the pressures are equal, quite independent of the unequal volumes of water in each tank.

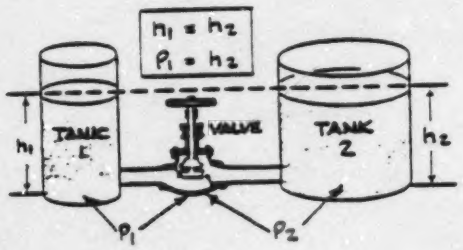


Fig. 1-23 Balanced pressures across valve.

MEASURING PRESSURES

The same principles we talked about in the illustration of the two tanks connected by a pipe are used in an instrument to measure gas pressure. This useful instrument is called a manometer. It is a U-shaped glass tube partially filled with mercury. Much heavier than water, mercury has a weight density 13.6 times that of water. Thus, since water has a weight density of 62.4 lb/ft^3, mercury has a weight density of 13.6 x 62.4 lb/ft^3 or 848.6 lb/ft^3.

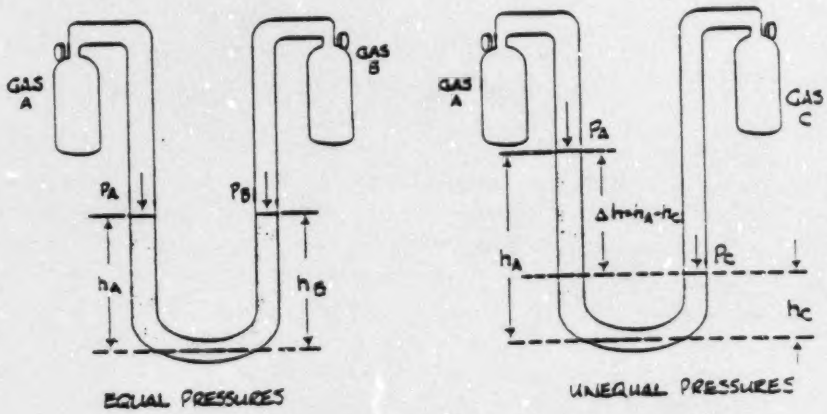


Fig. 1-24 Manometers are used to measure pressures.

In the left part of Figure 1-24, Gas A and Gas B are at the same pressure. Each exerts the same force per unit area on the two mercury columns in the U-tube. Since $P_A = P_B$, at the top of each mercury column, the mercury must be at the same level in each arm, so $h_A = h_B$. In the right part of Figure 1-24, Gas C is at a higher pressure than Gas A. It pushes down harder on the right column of mercury than does Gas A on the left column. The mercury column therefore moves down in the right arm and up in the left arm. By measuring the difference in height of the two columns of mercury in the U-tube, and using the equation $P = \rho gh$ discussed earlier, we can calculate the difference in pressure between Gas A and Gas C. Then, if we know the pressure of Gas A, we can calculate the pressure of Gas C. We shall try this in a laboratory exercise.

SELF-CHECK

1. Think about a washing machine. Is it made up of different energy systems? Can you name them?
2. Think about the fluid system in a washing machine. What are the parts? What causes the pressure that forces the water around?
3. Define **pressure** in your own words. What units are used to measure pressure?
4. Some bicycle tires are filled with air until the tire gage reads 55 lb/in^2.
   a. What is the gage pressure?
   b. What is the absolute pressure inside of the tire? (Assume a normal atmospheric pressure of 14.7 lb/in^2.)
   c. What is the absolute pressure outside of the tire?
   d. What is the net force on each square inch of the tire wall? Which direction does this force act?
5. Two cylindrical glass beakers of the same height are filled with water. One beaker has four times the diameter of the other, so it holds much more water.
   a. How do the pressures at the bottom of each beaker compare?
   b. Which beaker has the larger force pressing down on its bottom?
6. How much does one cubic foot of water weigh in pounds? in newtons?

7. What is the mass of one cubic centimeter of water in grams?
8. The height of the water level in a city water system is 150 feet above a faucet.
   a. What is the water pressure at the faucet in lb/in^2?
   b. What is the water pressure at the faucet in N/m^2?
9. How does a hydraulic jack develop large forces to lift heavy objects? Explain carefully. Use a rough drawing to help show your ideas.
10. Pressure depends on height, as we have learned. Because of this, one often gives the atmospheric pressure reading in terms like "750 mm Hg." What does this mean? How can a height of mercury in a tube be converted to real pressure units in N/m^2--or in lb/in^2?

INTERMEDIATE OBJECTIVE #2

Connect test system to measure force and pressure relationships.

LEARNING STEPS (Activities)

1. Refer to information sheets cited in Resource #1 for review of force in fluid systems.
2. Perform the activities cited in Resource #2 to learn how pressure and force are related.
3. Complete the test circuit procedure cited in Resource #3 to assure subject comprehension.
4. Complete the evaluation for this terminal objective.
5. Proceed to the learning guide cited in Resource #5.

RESOURCES

1. Information Sheet #1 begins on page 4.
2. Procedure Sheet #1 begins on page 16.
3. Procedure Sheet #1 test circuit procedure begins on page 18.
4. See your instructor for the evaluation instrument for this Intermedicate Objective.
5. See instructor for student learning guide 217.

Program	Task	Page
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PROCEDURE SHEET

- **SUBJECT:** PRESSURE & FORCE ACTIVITY

- **OBJECTIVE:** To advance and retract a double acting cylinder with 50 lbs. of force and retract with full line pressure with speed control

- **MATERIALS NEEDED:**
  1 - BRAT500 PNEUMATIC TRAINER
  1 - Single air piloted valve
  1 - Pneumatic input switch
  1 - Double Acting Cylinder
  1 - Pressure regulator
  1 - Flow control valve
  3 - Air line hoses with fast disconnects

- **PROCEDURE:** Using the above listed components, set up the pneumatic circuit as shown in illustrations 1 & 2.

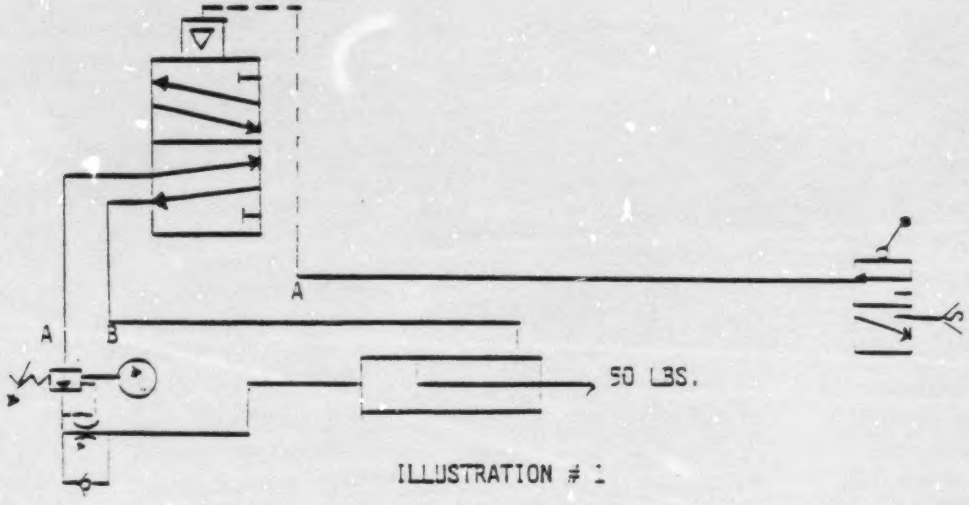


ILLUSTRATION # 1

FORMULA

FORCE (F) = PRESSURE (P) X AREA OF CYLINDER (A)

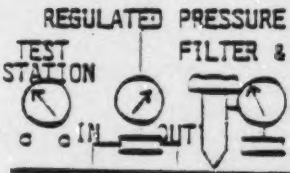
FORCE REQUIRED = 50 LBS.

$P = \frac{F}{A}$

$P = \frac{50}{A}$

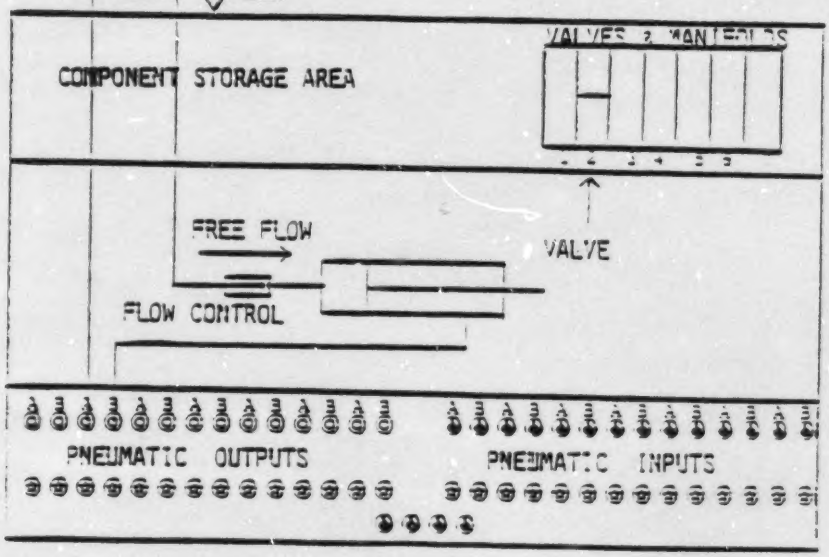
A = 1.228 sq. inch for 1 1/4" Bore

$P = \frac{50}{1.228}$ = 41 PSI (SET REGULATOR)



BRAT500 LAYOUT

*ADJUST REGULATOR TO 40 PSI



PNEUMATIC PILOT SWITCH

ILLUSTRATION = 2

Program	Task	Page
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TEST CIRCUIT PROCEDURE

- ☑ 1 - Check all connections as indicated in illustrations
- ☐ 2 - Adjust pressure with regulator to approx. 41 PSI on gauge
- ☐ 3 - Close flow control valve, then open 1/2 turn
- ☐ 4 - Activate air input switch; cylinder should move forward with 50 lbs. of force at full speed
- ☐ 5 - Deactivate air input switch, cylinder should retract slowly
- ☐ 6 - Adjust flow control for various speed observations

* FORMULA PROBLEM *

- ☐ 1 - Using the formula on the preceeding page, change the force required to 25 LBS and recalculate the formula below and reset the pressure regulator and follow the test circuit procedures with the new calculations.

FORCE REQUIRED = 25 LBS.

$P = \frac{\quad}{\quad}$

$P = \frac{\quad}{\quad}$.

$A =$

$P = \frac{\quad}{\quad} =$ PSI

PROGRAM INDUSTRIAL ELECTRICAL MAINENANCE

CRITERION EXAM

TASK = 216

DIRECTIONS:

THE PURPOSE OF THIS EXAM IS TO DETERMINE WHETHER OR NOT YOU HAVE UNDERSTOOD THE INFORMATION ON PRESSURE AND FORCE AS THEY APPLY TO A FLUID SYSTEM.

Each of the questions or incomplete statements below is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A,B,C or D) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer 10 out of 10 items correctly, 100 %.

EVALUATION SHEET

Complete the following questions.

1. What are the units for fluid pressure?_____

2. What is relative pressure?_____

_____

3. What is absolute pressure?_____

_____

4. Atmospheric pressure is a constant value_____

_____

5. How does a hydraulic jack develop large forces to raise heavy objects?

_____

_____

_____

6. How does a pressure regulator reduce pressure?_____

_____

7. A flow control valve reduces flow by_____

_____

8. Write the formula for calcutating pressure, force and area.

9.&10. How much does one cubic foot of water weigh in pounds?_____
In newtons?_____.

Illinois State Board of Education

Department of Adult, Vocational and Technical Education
Research and Development Section

Product Abstract

1. Title of material: Industrial Electrical Maintenance Task Listing by Occupational Titles

2. Date material was completed: FY85

3. Please check one: New material X Revised material ____ Field-tested material ____

4. Originating agency: Lake County Area Vocational Center

   Address: 19525 West Washington St., Grayslake IL Zip Code: 60030

5. Name(s) of developer(s): Melvin Whitmer

   Address: Lake County Area Vocational Center Zip Code: ____

6. Developed pursuant to Contract Number: R-99-25-X-0000-499

7. Subject Matter (Check only one according to Department of Education Code):

   Code

   ____ 01 Agricultural Education
   ____ 03 Business and Office Education
   ____ 04 Distributive Education
   ____ 07 Health Occupations Education
   ____ 09 Home Economics Education
   ____ 10 Industrial Arts Education
   ____ 16 Technical Education
   XX 17 Trade and Industrial Education
   ____ 22 Cooperative Education
   ____ Career Education
   ____ Other (Specify) ____

8. Education Level:

   ____ Pre-K Thru 6 ____ 7-8 ____ 9-10 X 11-12
   X Post-Secondary X Adult ____ Teacher (Pre-service)
   ____ Administrator (Pre-Service) ____ Other (Specify) ____

9. Intended for Use By:

   X Student X Classroom Teacher X Local Administrator
   ____ Teacher Educator ____ Guidance Staff ____ State Personnel
   ____ Other (Specify) ____

10. Student Type:

    X Regular ____ Disadvantaged ____ Handicapped
    ____ Limited-English Proficiency ____ Other (Specify) ____

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14. What level(s) of assistance is required to provide implementation of this outcome?

____ awareness
____ deciding
__X__ understanding
__X__ implementing

15. Are Consultive/Inservice (or staff development) available? Yes ____ No ____

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Research and Development Section, E-428
100 North First Street
Springfield, IL 62777
(217) 782-4620

16. General Description (State the general objective and suggested method of use. Summarize the content and tell how it is organized. Write the description so that it can be used to promote the material. Continue on back of this sheet or on another sheet, if necessary.)

Competency-based task listing by job titles to identify basic skills/knowledge

17. Person Completing this Abstract. Richard W. Glogovsky

Full Address
Lake County Area Vocational Center
19525 West Washington Street
Grayslake IL 60030

Zip ____

TASK LISTING BY OCCUPATIONAL TITLES

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY OCCUPATIONAL SAFETY OPERATION

4/85

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Describe Electrical Safety Practice	X	X	X	X	X	X	X	X	X	X	
	Demonstrate Safe Use of Hand Tools	X	X	X	X	X	X	X	X	X	X	
	Identify Hazzards of Static Electricity	X	X	X	X	X	X	X	X	X	X	
	Identify Shock Hazzards	X	X	X	X	X	X	X	X	X	X	

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY DESIGNING ELECTICAL DIAGRAMS

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR		
	Identify Electrical circuit & schematic symbols	X	X	X	X	X	X	X	X	X	X		
	Draw a basic electrical circuit using schematic symbols	X	X	X	X	X	X	X	X	X	X		

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY CONSTRUCTING FUNDAMENTAL D.C. CIRCUIT

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Describe Sources of Electricity	X	X	X	X	X	X	X	X	X	X	
	Describe Magnetism	X	X	X	X	X	X	X	X	X	X	
	Identify Battery Characteristics	X	X	X	X	X	X	X	X	X	X	
	Identify Electrical Conductors	X	X	X	X	X	X	X	X	X	X	
	Describe components of D.C. circuit	X	X	X	X	X	X	X	X	X	X	
	Explain OHMS Law	X	X	X	X	X	X	X	X	X	X	
	Differentiate between series & parallel circuits	X	X	X	X	X	X	X	X	X	X	
	Draw a series/parallel circuit	X	X	X	X	X	X	X	X	X	X	
	Construct a series/parallel circuit	X	X	X	X	X	X	X	X	X	X	

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY CONSTRUCTING FUNDAMENTAL A.C. CIRCUIT

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR		
	Describe Sources of A.C. Power	X	X	X	X	X	X	X	X	X	X		
	Use Oscilloscope to Identify Wave Forms	X		X	X	X	X			X	X		
	Calculate Inductance	X		X	X	X	X			X	X		
	Calculate Inductive Reactance	X		X	X	X	X			X	X		
	Construct a Seriels RL Circuit	X		X	X	X	X			X	X		
	Measure Voltage Across Resistor & Inductor at Varing Frequencies in a Series RL Circuit	X		X	X	X	X			X	X		
	Calculate Capacitance and Capacitive Reactance	X		X	X	X	X			X	X		
	Construct a Series RC Circuit	X		X	X	X	X			X	X		
	Measure Voltage Across Resistor &												

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY CONSTRUCTING FUNDAMENTAL A.C. CIRCUIT

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Capacitor at Varying Frequencies											
	In a Series RC Circuit	X		X	X	X	X	X	X	X	X	
	Construct a Series RLC Circuit	X		X	X	X	X	X	X	X	X	
	Measure Voltage Across Resistor,											
	Capacitor, & Inductor at Various											
	Values of Capacitane in a Series											
	Circuit	X		X	X	X	X	X	X	X	X	
	Measure Voltage Across Resistor,											
	Capacitor, and Inductor at Various											
	Values of Inductance in a Series											
	Circuit	X		X	X	X	X			X	X	
	Calculate Power Factor	X		X	X	X	X			X	X	
	Construct Parallel RLC Circuit	X		X	X	X	X			X	X	

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY CONSTRUCTING FUNDAMENTAL A C CIRCUIT

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR		
	Measure Current Through Resistor, Capacitor, and Inductor at Various Values of Capacitance in a Parallel Circuit	X		X	X	X	X			X	X		
	Measure Current Through Resistor, Capacitor, and Inductor at Various Values of Inductance in a Parallel Circuit	X		X	X	X	X			X	X		
	Calculate Unity Power Factor	X		X	X	X	X			X	X		

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY: INTERPRETING ARCHITECTURAL PLANS

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Read Architectural Plans		X				X			X	X	

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY: CALCULATING RESIDENTIAL CIRCUIT REQUIREMENT

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR		
	Identify Feeder and Branch Circuit Requirements	X	X	X						X	X		
	Calculate Feeder and Branch Circuit Requirements	X	X	X						X	X		
	Identify Appliance Circuit Requirements		X							X	X		
	Calculate Appliance Circuite Requirements		X							X	X		
	Identify Service Entrance Requirements	X	X							X	X		
	Calculate Service Entrance Requirements	X	X							X	X		
	Determine Branch Circuites Desired	X	X							X	X		

PROGRAM: INDUSTRIAL ELECTRICAL MAINTENANCE

DUTY RUNNING AND INSTALLING CONDUIT

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Describe Types of Conduit	X	X	X					X	X	X	
	Demonstrate NEC Procedures for Cutting, Bending, and Connecting Conduit	X	X	X					X	X	X	
	Identify Receptacle Parts	X	X	X					X	X	X	
	Identify Switches and Connections	X	X	X					X	X	X	
	Identify Conduit Run Symbols	X	X	X					X	X	X	
	Draw a Conduit Run	X	X	X					X	X	X	
	Install Conduit between Boxes	X	X	X					X	X	X	

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY DESIGNING GROUNDING SYSTEM

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR		
	Identify NEC Articles for Grounding Systems	X	X	X	X	X	X	X	X	X	X		
	Draw a Wiring Diagram for Grounded System	X	X	X	X	X	X	X	X	X	X		

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY: CALCULATING CIRCUIT PROTECTION DEVICES

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Identify Fuse Characteristics	X	X	X	X	X	X	X	X	X	X	
	Identify Circuit Breaker Characteristics	X	X	X	X	X	X	X	X	X	X	
	Describe Overload Relay Application	X	X	X	X	X	X	X	X	X	X	
	Identify NEC Articles for Circuit Protection Devices	X	X	X	X	X	X	X	X	X	X	
	Calculate Current for Protection Devices	X	X	X	X	X	X	X	X	X	X	

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY INSTALLING SERVICE ENTRANCE PANEL

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR		
	Select Appropriate Service Entrance Material	X	X	X	X	X	X		X	X	X		
	Identify Proper Service Wiring	X	X	X	X	X	X		X	X	X		
	Install & Wire Service Entrance Panel	X	X	X	X	X	X		X	X	X		

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY CALCULATING WIRE SIZE & DERATING

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR
	Identify Wire Size	X	X	X	X	X	X	X	X	X	X
	Identify Type of Wire Insulation as recommended by NEC	X	X	X	X	X	X	X	X	X	X
	Calculate Wire Derating IDentify Wire Sizes	X	X	X	X	X	X	X	X	X	X
	Cacluate for Wire Derating Factors	X	X	X	X	X	X	X	X	X	X

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY ROUGHING A HOUSE

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR		
	Demonstrate Attaching Conduit to Support Mechanism		X				X		X		X		
	Demonstrate Running Conduit Through Masonary Obstacles		X				X		X		X		
	Demonstrate Proper Wire Pulling Methods		X				X		X		X		

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY FINISHING A HOUSE

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Install Protective Devices		X									
	Install Electrical Devices		X						X		X	
	Install Appliance Branches		X						X		X	

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY INSTALLING LUMINARY FIXTURES

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR		
	Identify Installation Procedures for Luminary Fixtures	X	X	X					X	X	X		
	Describe Luminary Fixtures	X	X	X					X	X	X		
	Install Luminary Fixtures	X	X	X					X	X	X		

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY INSTALLING ELECTRICAL ENVRIONMENTAL CONTROL SYSTEMS

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Identify Heating System Components	X	X	X			X				X	
	Identify NEC Articles for Heating Devices	X	X	X			X				X	
	Connect A.C. Power to Heating Device	X	X	X			X				X	
	Identify Air Conditioning Electrical Requirements	X	X	X			X				X	
	Connect Air Conditioning Power	X	X	X			X				X	

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY INSTALLING LOW VOLTAGE POWER DEVICES

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR		
	Identify Circuit Symbols	X	X	X	X	X	X	X	X	X	X		
	Identify All Low Voltage Power Devices	X	X	X	X	X	X	X	X	X	X		
	Identify Componets in a Low Power Circuit	X	X	X	X	X	X	X	X	X	X		
	Connect Low Power Devices	X	X	X	X	X	X	X	X	X	X		

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY CONNECTING TRANSFORMERS

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHAN.	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Identify Three Phase Sine Wave Components	X		X	X		X				X	
	Discuss Transformer Impedance	X		X	X		X				X	
	Describe Transformer Construction Elements	X		X	X		X				X	
	Identify Delta and Wye Connections	X		X	X		X				X	
	Connect Transform for Three Phase Wye Operation	X		X	X		X				X	
	Connect Transformer for Three Phase Delta Operation	X		X	X		X				X	
	Connect Two Single Phase Transformer In Parallel	X		X	X		X				X	
	Connect Dual Voltage Transformer	X		X	X		X				X	

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY CONNECTING & MAINTAING AC/DC ROTATING EQUIPMENT

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Describe Electrical System Work	X		X			X					
	Identify Sources of Counter Electromotive Forces	X		X			X					
	Describe Armature Characteristics	X		X			X					
	Connect DC Motor for Series & Shunt Operations	X		X			X					
	Maintain DC Motors	X		X			X					
	Describe Single Phase Starting Tech.	X		X			X					
	Describe Three Phase Induction Motor	X		X			X					
	Describe Synchronous Motor	X		X			X					
	Connect Delta & Wye Motor	X		X			X					
	Maintain AC Motor	X		X			X					
	Describe Motor Performance Character	X		X			X					

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY CONSTRUCTING POWER SUPPLIES

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNIGIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR
	Construct a Transformer	X		X	X	X	X			X	X
	Construct Regulated Power Supply	X		X	X	X	X			X	X
	Construct Overcurrent Protector	X		X	X	X	X			X	X
	Identify Components of Switching Power Supply.	X		X	X	X	X			X	X
	Test Switching Power Supply	X		X	X	X	X			X	X

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY CONNECTING MANUAL PROCESS CONTROL DEVICES

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Identify Manual Process Control Devices	X		X	X	X	X	X		X	X	
	Describe Ladder Diagram Symbols	X		X	X	X	X	X		X	X	
	Connect Manual Process Control Devices	X		X	X	X	X	X		X	X	

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY CONNECTING PROCESS SENSOR JUNCTIONS

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHAN	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR
	Identify Chemical Sensor Junctions	X		X	X	X	X	X		X	X
	Connect Chemical Sensor Junction Devices	X		X	X	X	X	X		X	X
	Identify Radiant Sensor Junctions	X		X	X	X	X	X		X	X
	Connect Radiant Sensor Junction Devices	X		X	X	X	X	X		X	X
	Identify Semi-Conductor Sensor Junctions	X		X	X	X	X	X		X	X
	Connect Semi-Conductor Sensor Junction Devices	X		X	X	X	X	X		X	X
	Identify Pressure Sensing Devices	X		X	X	X	X	X		X	X
	Connect Pressure Sensing Devices	X		X	X	X	X	X		X	X
	Identify Magnetic Sensing Devices	X		X	X	X	X	X		X	X

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY CONNECTING PROCESS SENSOR JUNCTIONS

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Connect Magnetic Sensing Devices	X		X	X	X	X	X		X	X	
	Identify Mechanical Position Sensor	X		X	X	X	X	X		X	X	
	Connect Mechanical Sensors	X		X	X	X	X	X		X	X	
	Identify Ladder Diagram Symbol for Process Devices	X		X	X	X	X	X		X	X	

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY CONNECTING SIGNAL PROCESSORS

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHAN	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR
	Identify Operational Amplifiers	X		X	X	X	X	X		X	X
	Connect Operational Amplifiers	X		X	X	X	X	X		X	X
	Identify Pulse Generators	X		X	X	X	X	X		X	X
	Connect Pulse Generators	X		X	X	X	X	X		X	X
	Identify DC to AC Converters	X		X	X	X	X	X		X	X
	Connect DC to AC Concerter	X		X	X	X	X	X		X	X
	Identify AC to DC Converter	X		X	X	X	X	X		X	X
	Connect AC to DC Converter	X		X	X	X	X	X		X	X
	Identify Signal Conditioning Circuit	X		X	X	X	X	X		X	X
	Connect Signal Conditioning Circuit	X		X	X	X	X	X		X	X

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY CONNECTING PROCESS LOGIC DEVICES

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Identify Gate Logic Devices	X		X	X	X	X	X		X	X	
	Connect Gate Logic Devices	X		X	X	X	X	X		X	X	
	Identify Timing Logic Devices	X		X	X	X	X	X		X	X	
	Connect Timing Logic Devices	X		X	X	X	X	X		X	X	
	Identify Counting Devices	X		X	X	X	X	X		X	X	
	Connect Counting Devices	X		X	X	X	X	X		X	X	
	Identify Ladder Diagram Symbols for Process Logic Devices	X		X	X	X	X	X		X	X	

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY INSTALLING AND MAINTAINING PROCESS ACTUATORS

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHAN	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR
	Identify Fluid System Symbols	X		X	X	X	X			X	X
	Describe Unified Technology Concepts	X		X	X	X	X			X	X
	Connect Fluid System Valves	X		X	X	X	X			X	X
	Identify Fluid System Components	X		X	X	X	X			X	X
	Connect Fluid System Components	X		X	X	X	X			X	X
	Connect Venturi Vacuum Generator	X		X	X	X	X			X	X
	Describe Pressure and Force in a Fluid System	X		X	X	X	X			X	X
	Describe Fluid Conditioners	X		X	X	X	X			X	X
	Connect Pneumatic Arm Controlls	X		X	X	X	X			X	X
	Troubleshoot Fluid System	X		X	X	X	X			X	X

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY IDENTIFYING PROCESS SYSTEM COMPONENT

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR
	Describe Telemetry Components			X		X				X	
	Describe System Interface Component			X		X				X	
	Describe Process Control Components			X		X				X	

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY CLASSIFYING ROBOTS & ROBOTIC CONTRO ELEMENTS

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHAN.	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Describe Robotic Types	X		X	X	X				X		
	Describe Robotic Control Parts	X		X	X	X				X		
	Describe Feedback Signal Systems	X		X	X	X				X		

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY IDENTIFYING ROBOTIC SYSTEM COMPONENTS

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR		
	Identify Robotic System Mechanical												
	Parts	X		X	X	X				X			
	Identify BRAT 800 Pneumatic Actuator												
	Parts	X		X	X	X				X			

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY PROGRAMMING BRAT 800

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHAN	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR	
	Write a Robotic Program			X	X	X				X		
	Test Program via Magnetic Logic Device			X	X	X				X		
	Program Robot with Drum Controller			X	X	X				X		
	Operate Programmed Robot			X	X	X				X		

PROGRAM: INDUSTRIAL ELECTICAL MAINTENANCE

DUTY TROUBLESHOOTING BASIC SYSTEMS

TASK NO.	TASK DESCRIPTION	ELECTRICIAN - COMMERCIAL	ELECTRICIAN - RESIDENTIAL	ELECTRICAL/ELECTRONIC TECH.	ELECTRONIC EQUIPMENT MECHANIC	COMPUTER SERVICE TECHNICIAN	APPLIANCE INSTALLER/REPAIRER	ELECTRONIC ASSEMBLER	ELECTRICIAN'S HELPER	ELECTRICAL ENGINEER	ELECTRICAL INSPECTOR		
	Troubleshoot and Repair Control Circuits and Control Devices	X		X	X	X							
	Troubleshoot using Electrical Schematics, Building Plans, and Ladder Diagrams	X		X	X	X							
	Identify Troubleshooting Short Cuts	X		X	X	X							
	Troubleshoot Input and Output Instrumentation Devices	X		X	X	X							
	Troubleshoot Integrated Circuit Logic Devices	X		X	X	X							
	Troubleshoot Programmable Controlle			X	X	X							
	Troubleshoot Microprocessor Logic System			X	[redacted]	X							

END

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DATE FILMED

NOVEMBER

25 _1985